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Moab Project

Characterization of Groundwater Brine Zones at the Moab Project Site (Phase I)

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Complete Appendices will be provided upon request. Please email moabcomments@gjem.doe.gov to request.

Acronyms

Atlas	Atlas Minerals Corporation
bgs	below ground surface
btoc	below top of casing
DOE	U.S. Department of Energy
ESL	Environmental Sciences Laboratory
ft	feet
ft^2	square feet
gpm	gallons per minute
h	hour
HDPE	high density polyethylene
:S/cm	microSiemens per centimeter
mg/L	milligrams per liter
mL	milliliter
MSL	mean sea level
TDS	total dissolved solids

Executive Summary

A saltwater brine zone underlies fresh water in the unconfined alluvial system at the Moab Project Site. Saltwater intrusion could degrade the overlying freshwater, which could adversely affect the tamarisk plant communities that are providing beneficial phytoremediation at the site. In addition, saltwater intrusion into the shallow groundwater may also bring higher ammonia concentrations to the surface and cause added contamination to the river. The relationship between drawdown in a remediation extraction well at a given pumping rate and upconing response in the underlying brine zone is required to support the design of an interim remedial action to reduce risk to endangered fish from ammonia discharge to the river.

The primary objective of this investigation was to establish an empirical relationship between the pumping rate and drawdown from the overlying freshwater zone and any associated brine up coning that may result. Instrumentation was installed to monitor brine potential upconing in the area of the plume during pumping. Specific conductance probes were installed in the upper silty sand portion of the aquifer and the middle and lower gravelly sand portions of the aquifer where the pumping occurred. Pumping tests were performed using a pumping well (screened from the top of the freshwater zone and extending into the lower brine) with variable pumping rates (5, 15, and 55 gallons per minute) and variable pump intake depths.

Observations of chemistry versus time during the pumping tests revealed that chemical conditions in the silty sand zone were unaffected by pumping. However, chemistry in the gravelly sand zone did change during pumping, as evidenced by increased specific conductance in the pumping well discharge water. These results suggest that preferential flow pathways within a more conductive hydrostratigraphic unit occurring in the lower gravelly portions of the aquifer may be responsible for the increase in salinity levels observed in the discharge water from the pumping well, rather than upconing from the brine.

Additional testing is required to determine if the increase in salinity levels observed in the discharge water from the pumping well is a result of the well construction (i.e. well screened over fresh water and brine zone) or due to brine upconing. It is recommended that a new pumping well is installed that is screened only in the upper freshwater zone (within the silty sand portion of the aquifer) and a longer duration test conducted.

End of current text

1.0 Introduction

The Moab Project Site is a former uranium-ore processing facility located approximately 3 miles northwest of the city of Moab in Grand County, Utah. The plant was constructed in 1956 by the Uranium Reduction Company, which operated the mill until 1962 when the assets were sold to the Atlas Minerals Corporation (Atlas). Operations continued under Atlas until 1984. When the processing operations ceased in 1984, approximately 130 acres of mill tailings had been impounded in an unlined pond located near the northwest portion of the property. Atlas placed an interim cover over the tailings pile as part of decommissioning activities on going between 1988 and 1995. In October 2001, the title of the property and responsibility for remediation of the tailings pile and contaminated groundwater beneath and downgradient from the site was transferred to the U.S. Department of Energy (DOE).

Results of previous investigations (ORNL 1998 and SMI 2001) suggest that the former operating practices have affected the shallow groundwater with site-related contaminants. Characterization data indicate that some of the more mobile contaminants have infiltrated to the ground water and are migrating downgradient from the tailings pile in a plume that is discharging to the Colorado River. Additional characterization of the aquifer was needed to support the design of an interim remedial action to reduce risk to endangered species of fish from ammonia discharge to the river (DOE 2001).

End of current text

2.0 Scope

The results presented in this report are intended to provide empirical data regarding the upconing of brine in a well pumping from the overlying freshwater system. Freshwater in the unconfined alluvial system at the Moab Project Site is underlain by a saltwater brine zone. Saltwater intrusion would result in degradation of the overlying freshwater, which could adversely impact the tamarisk plant communities that are providing beneficial phytoremediation at the site. In addition to causing saltwater intrusion into the shallow groundwater, rising saltwater may bring higher ammonia concentrations to the surface and cause added contamination to the river.

These results will ultimately assist in the preparation of a design for an interim remedial action to reduce risk to potentially sensitive habitat along the Colorado River that is affected by relatively high ammonia concentrations.

The primary objectives for this field investigation, as presented in the *Work Plan for Characterization of Groundwater Brine Zones for Interim Remediation Activities at the Moab, Utah, UMTRA Project Site* (DOE 2002a) include:

- Characterizing the freshwater-brine contact at several existing pumping well locations.
- Evaluating the relationship between drawdown in the freshwater zone and upconing response in the brine zone at different pumping rates and pump intake locations.
- Determining the maximum pumping rate that can be sustained without any rise in the underlying brine zone.

A secondary objective of this study was to acquire additional data to determine hydraulic parameters of the shallow aquifer. However, because of the density differences in the ground water due to the brine, not all the data collected during these tests may be applicable for aquifer parameter analysis.

End of current text

3.0 Background

The site overlies an aquifer that consists of a mixture of Quaternary alluvium, talus, and eolian deposits. These deposits are divided into shallow sandy sediments and deeper gravelly sediments. The shallow deposits are fine-grained, well-graded sands and silts that range in thickness from approximately 8 to 30 feet (ft) and average of 20 ft. Gravelly sands and sandy gravels make up the deeper alluvium; the thickness is dependent upon the depth to bedrock. Depth to bedrock varies dramatically across the site, and the range of thickness is not clearly defined. The available data indicates that bedrock crops out north of Highway 191 and is greater than 400 ft below the ground surface near the southeast corner of the tailings pile.

Three existing well clusters installed by Shepherd Miller, Inc. (SMI), were used during this investigation, as shown on Figure 1. The wells in the clusters are identified in this report as follows:

SMI Well Number	Reference Number
SMI-PW01	PW01
SMI-PZ1S	PZ1S
SMI-PZ1M	PZ1M
SMI-PZ1D	PZ1D
SMI-PW02	PW02
SMI-PZ2M1	PZ2M1
SMI-PZ2M2	PZ2M2
SMI-PZ2D	PZ2D
SMI-PW03	PW03
SMI-PZ3S	PZ3S
SMI-PZ3M	PZ3M
SMI-PZ3D2	PZ3D2

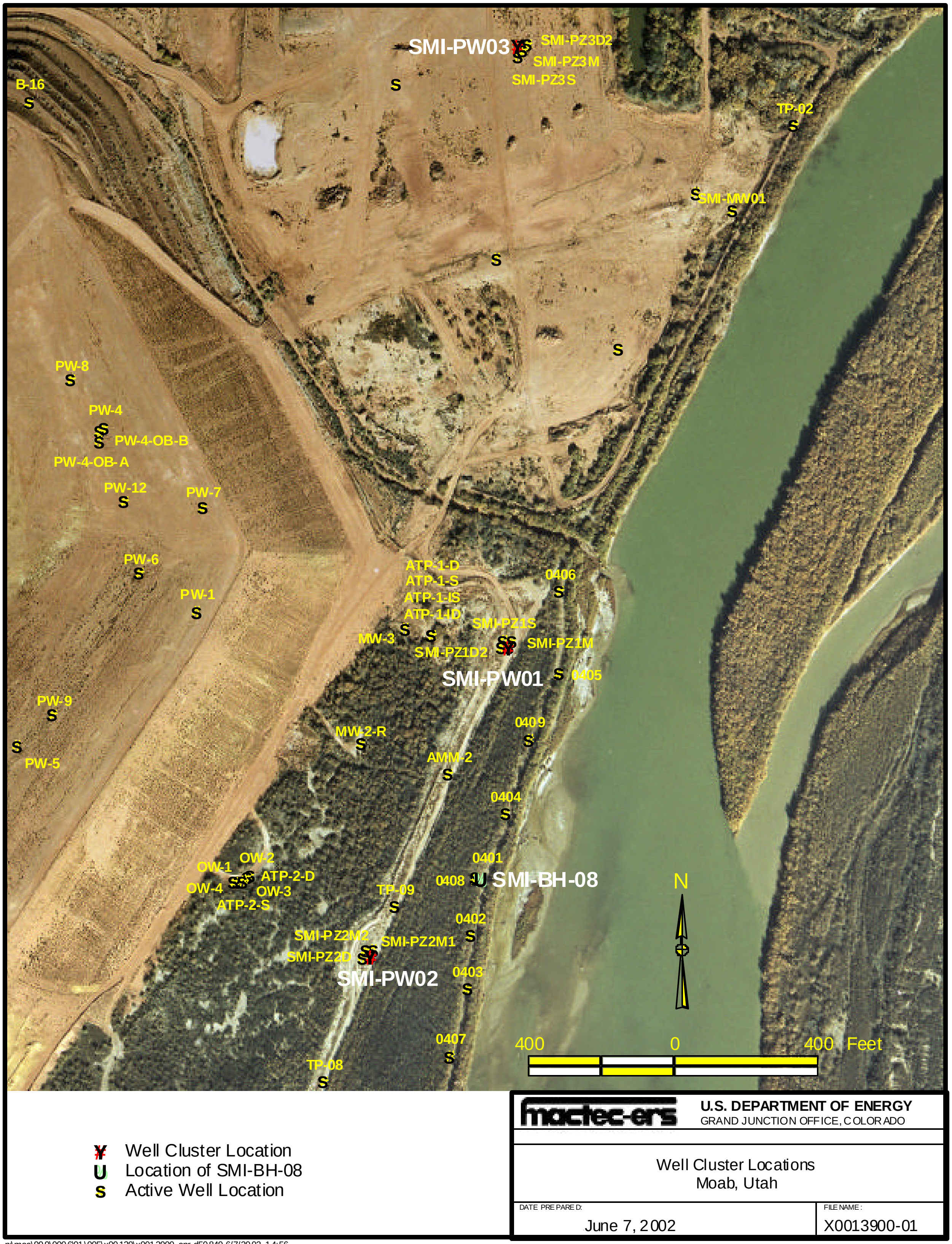


Figure 1. Well Locations

4.0 Test Procedures

4.1 Pumping Well Clusters Baseline Profile

Prior to conducting the aquifer tests, the field team collected groundwater samples at each of the three pumping well clusters to provide baseline data (Figure 1). Each cluster consists of a pumping well screened from approximately 20 to 60 ft below ground surface (bgs) and three observation wells that were completed at various depths with a 5-ft screen. Figures 2, 3, and 4 provide map views and cross-sections of the PW01, PW02, and PW03 well clusters, respectively.

These groundwater samples were collected at 5-ft intervals using a peristaltic pump, with the pump intake attached to the end of a line that was lowered down the well. Prior to the collection of each sample, the intake line was purged to ensure the sample was representative of the desired depth. To confirm that the line was adequately purged, a YSI meter was set up at the surface to monitor the temperature, pH, and conductivity of the discharge from the peristaltic pump. The sample was not collected until the field parameters measured by the YSI meter stabilized.

The samples were filtered in the field using a 0.45 micrometer (μm) filter and collected in a 500-milliliter (mL) HPDE container. Each sample was analyzed at the Environmental Sciences Laboratory (ESL) for density, conductivity (which was later converted to specific conductance), ammonia (as nitrogen [N]), chloride, sulfate, and uranium. A 125-mL split of each sample was submitted to the Grand Junction Office Analytical Laboratory for Total Dissolved Solids (TDS) analysis.

All analytical data are reported in the data package produced by the ESL. A copy is presented in Appendix A.

Because the observation wells consist of only a 5-ft screen, only one sample (collected near the midpoint of the screen) was collected from each observation well. Sampling procedures and analyses are the same as those discussed for the pumping wells.

As in the ESL report *Chemistry of Ground Water in the Colorado River Sandbar Area* (DOE 2002b), analysis of the data collected from this baseline study includes the use of the sulfate/chloride ratio. Data presented in the ESL report suggest a trend in chloride and sulfate concentrations with depth in the alluvial groundwater. The deeper groundwater tends to have higher chloride concentrations due to underlying salt bed interaction, and the shallow groundwater that has been affected by millsite activity has higher sulfate concentrations.

The sulfate/chloride ratio may allow for further designation of groundwater types identified during the investigation. In general, samples collected from greater depths of the aquifer have lower ratios. Samples containing high ratios are indicative of water more influenced by millsite operations and less influenced by the underlying brine.

4.2 PW01 Cluster Aquifer Test Data Collection: Water Chemistry Analysis

During the aquifer tests, field parameters (conductivity, temperature, and pH) and water levels data were measured. All field parameter data were collected using the *In-Situ* Troll 8000 probes, which measure the field parameters inside wells (i.e., there is no need to pump the water to the surface to measure the parameters). The pumping well and each of the three observation wells were equipped with these probes; Table 1 shows the depths at which they were set.

Table 1. Sample Collection Depths for PW01 Cluster Tests

Well	PW01	PZ1S	PZ1M	PZ1D
Depth of Sampling	Test Dependent	19 ft btoc	60 ft btoc	75 ft btoc

ft = feet; btoc = below top of casing

Data were downloaded and subsequently imported into the *In-Situ* software program *CondCal*, which modifies the conductivity data. This software uses individual probe conductivity calibration data to develop a conductivity calibration curve. *CondCal* then generates a file of updated conductivity and specific conductance data.

Data collected by the Troll 8000 probes provide useful information regarding the trend of the specific conductance data over time as opposed to the actual specific conductance values. To obtain the most accurate specific conductance data, groundwater samples were collected for laboratory analysis.

Groundwater samples were collected using a peristaltic pump with the intake attached to the Troll 8000 probes. Groundwater sampling procedures were the same as those described during the profile baseline sampling, and the samples were submitted for the same analyses. These samples were collected at various times during the test interval, generally at the beginning, near the middle, and at the end of the pumping phase. Because the conductivity measurement is sensitive to temperature, this value was converted to specific conductance to correct for temperature differences among the measurements. The conductivity values were converted to specific conductance based on the equation presented in the In-Situ Troll 8000 manual:

$$SC = C / (1+0.0191 \times [T-25])$$

where SC = specific conductance and C = the conductivity measured at temperature T (°C).

4.3 Aquifer Test Data Collection: Aquifer Test Drawdown Data Analysis

All water level data were collected from the pumping well and adjacent observation wells using pressure transducers connected to a Hermit 3000. Data were also collected using a sounder during various times of the test to confirm that the water level data collected by the transducers was correct.

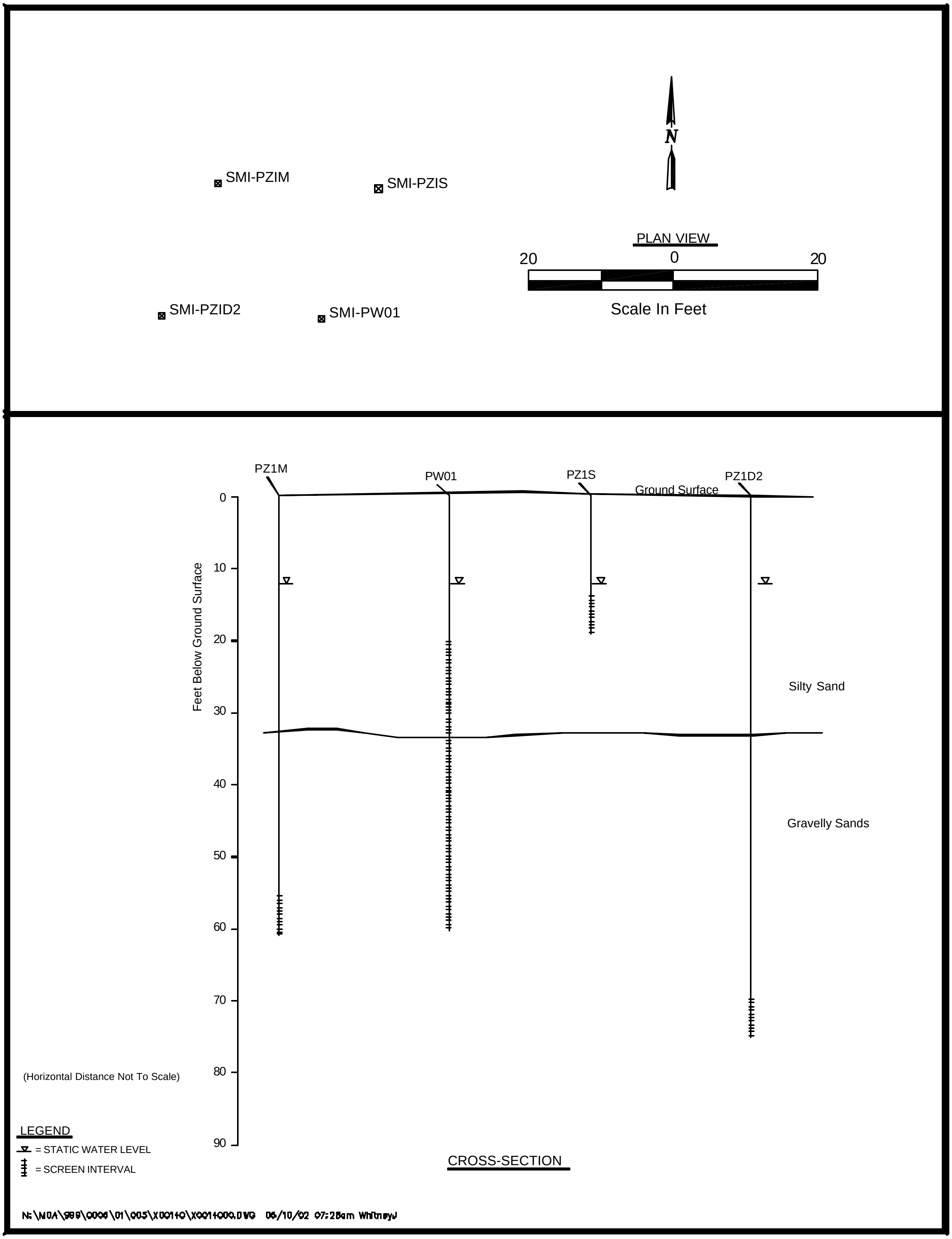


Figure 2. PW01 Well Cluster Map and Cross-Section

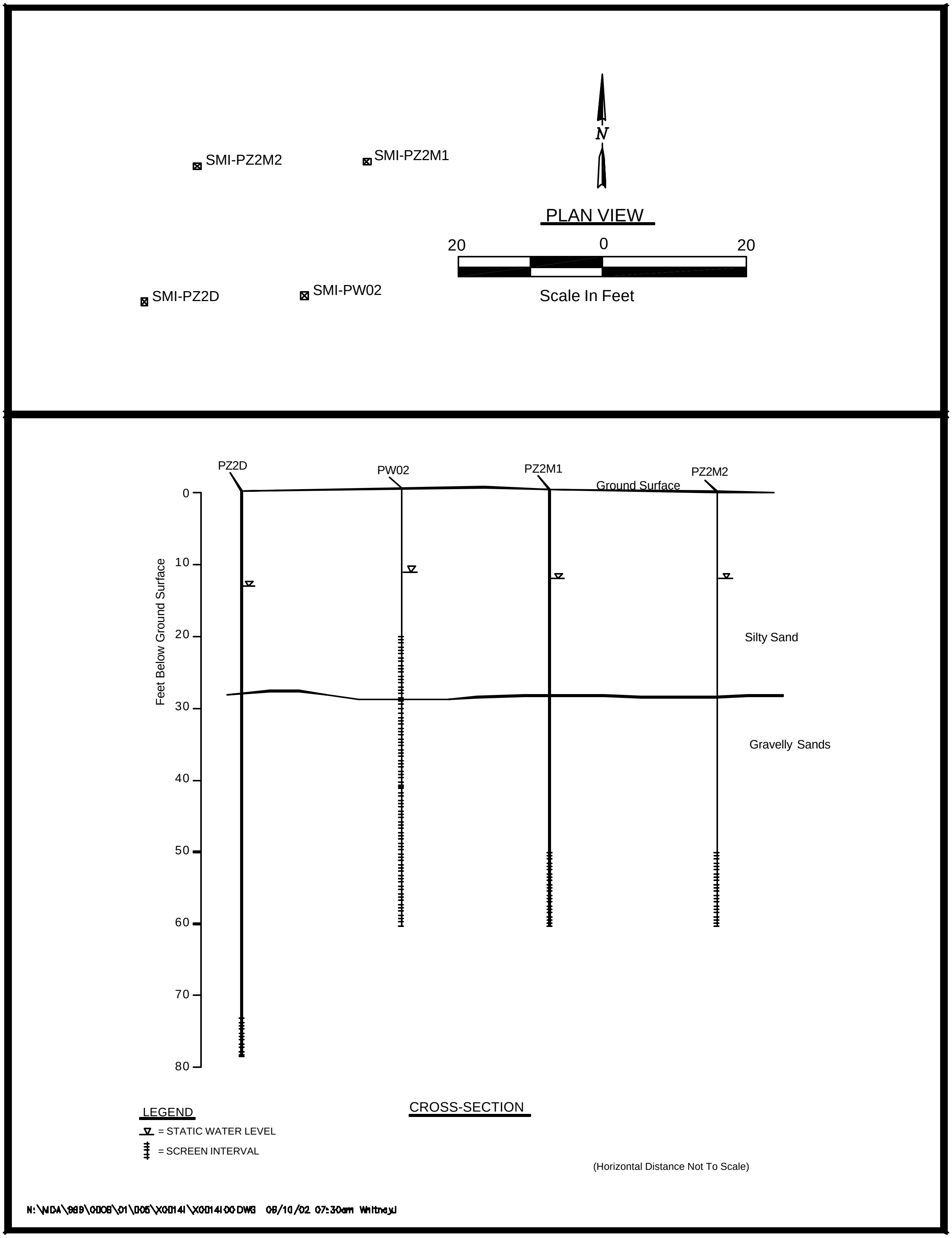


Figure 3. PW02 Well Cluster Map and Cross-Section

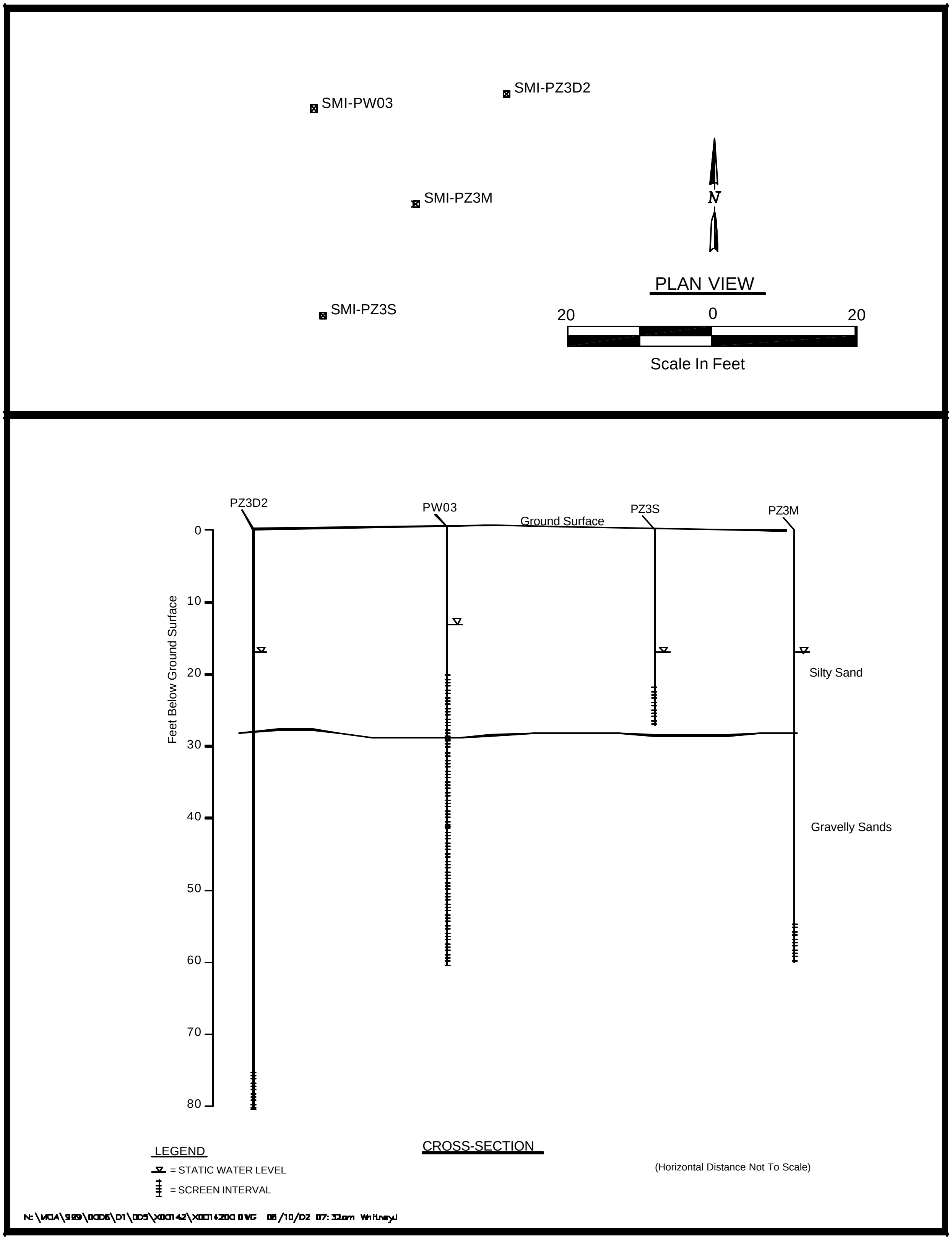


Figure 4. PW03 Well Cluster Map and Cross-Section

Analysis of these data provided estimates of the transmissivity and hydraulic conductivity of the gravel unit within the alluvial aquifer. All water generated from each test was discharged over a contaminated onsite location a minimum of 200 ft from the pumping well or observation wells away from the river, to the west.

Drawdown and residual drawdown data collected during the tests were analyzed using the software package Aquifer Win32 (Environmental Simulations, Inc., 1999). This software package allows the user to analyze the data with a number of different analytical methods. Because the alluvial aquifer is unconfined and the pumping and observation wells partially penetrate the total thickness of the aquifer, the drawdown data collected from observation wells during the pumping phase of the tests were analyzed using the Hantush partial penetration modification of the Theis Method (Hantush 1961). The data collected from the observation wells and pumping wells during the recovery phase of the aquifer tests were analyzed using the Theis Recovery Method (Kruseman and DeRidder 1991).

Aquifer parameters were not estimated from the drawdown data collected from observation well PZ1S because this well is not screened within the same hydrologic unit as pumping well PW01. Well PZ1S is screened exclusively in the shallower sandy sediments, and PW01 is screened primarily within the deeper gravelly sediments.

The data collected from observation well PZ1D were also not used to estimate aquifer parameters due to the high density of groundwater in this well. PZ1D is screened from 70 to 75 ft bgs, and the groundwater specific conductance was measured to be approximately 140,000 microSiemens per centimeter (:S/cm) during the baseline investigation. Because of the high density, there was less drawdown measured during the tests compared to drawdown from a well completed in a freshwater zone. As a result, the data collected during the aquifer tests are not considered representative and were not included in the aquifer parameter analyses.

Data collected from PZ1M during the pumping and recovery phases, in addition to the data collected from PW01 during the recovery tests, were used to estimate the aquifer parameters.

5.0 Results—Baseline Sampling

5.1 PW01 Cluster

Sampling at the PW01 cluster was completed on February 14, 2002. Table 2 lists initial water levels along with other pertinent well data. Figure 2 presents a map view and cross-section of the PW01 well cluster.

Table 2. PW01 Well Cluster Data and Static Water Levels

Well	Screen Interval (ft bgs)	2/14/02 Depth to Water (ft btoc)	2/14/02 Groundwater Elevation (ft MSL)
PW01	20.1 – 60.1	13.70	3,954.62
PZ1S	13.9 – 19.1	14.48	3,954.65
PZ1M	55.5 – 60.8	13.59	3,954.70
PZ1D	69.8 – 75.0	14.17	3,954.09

bgs = below ground surface; btoc = below top of casing; ft = feet; MSL = mean sea level

Table 3 presents the results from the baseline sampling. Included in this table are depths at which the samples were collected and the sample temperature and pH at the time the sample was collected. In addition, this table provides the sample temperature (T) at time of analysis and the corresponding sample density, conductivity, and specific conductance (SC). Table 3 also includes results for ammonia (NH_3 as N), chloride (Cl), sulfate (SO_4), uranium (U) and TDS.

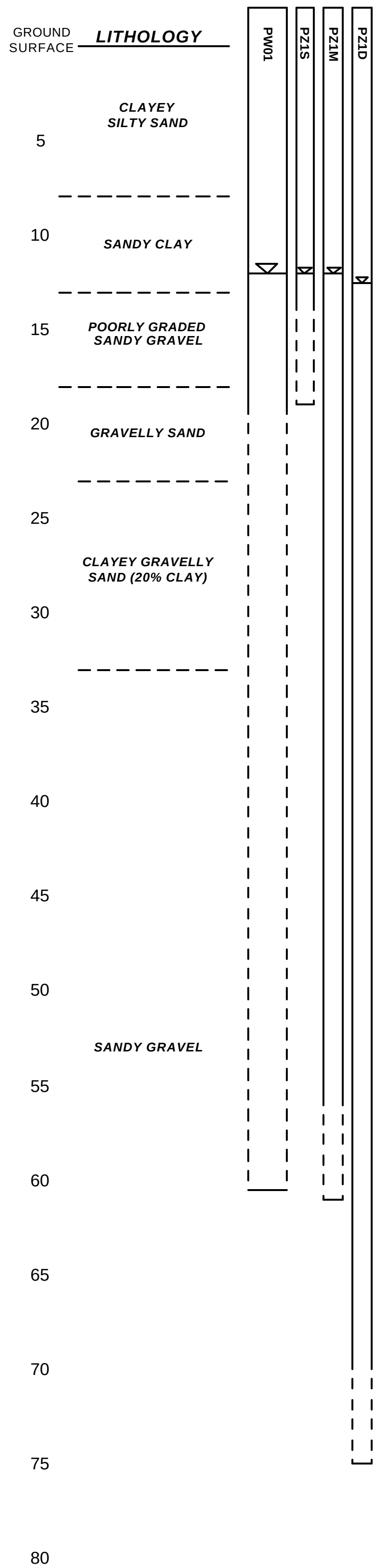
Table 3. PW01 Baseline Sampling Results

Well	Depth	Field		Laboratory				Analytes (mg/L)				
	(ft btoc)	pH	T	T	Cond	SC	Density	NH_3	Cl	SO_4	U	TDS
PW01	23	6.54	16.0	18.4	15,170	17,358	1.0095	500	1,448	7,325	1.224	12,400
PW01	28	6.55	16.2	20.9	14,870	16,133	1.0094	490	1,425	7,167	1.204	12,100
PW01	33	6.62	15.7	20.5	16,930	18,522	1.0102	770	1,391	8,775	1.762	13,525
PW01	38	6.66	15.3	20.6	18,740	20,459	1.0106	860	1,447	10,147	2.117	15,113
PW01	43	6.72	16.4	20.8	22,800	24,789	1.0133	860	1,599	11,905	2.512	18,120
PW01	48	6.71	15.2	20.7	22,840	24,884	1.0134	840	1,615	11,844	2.505	18,540
PW01	53	6.73	15.6	20.6	26,560	28,997	1.0155	980	2,147	13,348	2.867	20,580
PW01	58	6.60	15.7	20.6	68,280	74,545	1.0333	1,620	16,518	14,569	3.064	46,100
PW01	62	6.58	16.4	20.6	71,120	77,645	1.0336	1,560	16,998	14,510	2.974	46,350
PZ1S	19	6.61	15.5	20.7	15,540	16,931	1.0074	480	1,443	7,338	1.345	12,325
PZ1M	60	6.64	15.8	20.7	47,080	51,293	1.0252	1,500	8,768	15,676	3.613	34,433
PZ1D	75	6.43	16.2	20.8	128,320	139,512	1.048	2,350	46,772	8,759	1.053	77,600

Notes: Depth measured as ft below top of casing; All temperature data measured as °C; Density measured as grams per cubic centimeter (g/cm^3)
Cond = conductivity (µS/cm); SC = specific conductance (µS/cm); mg/L = milligrams per liter

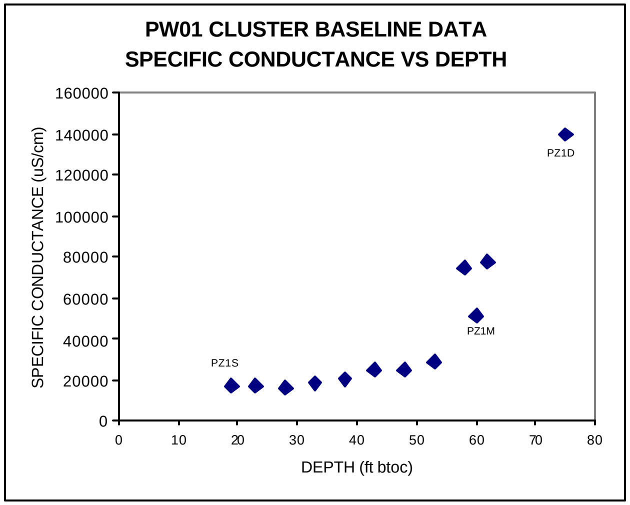
Hanshaw and Hill (1969) define brine as having the same salt content as sea water (TDS = 35,000 milligrams per liter [mg/L]). Based on this definition, the brine zone surface at the PW01 location was encountered between 53 and 58 ft below top of casing (btoc). TDS data collected from PZ1M suggests the brine surface is present at approximately 60 ft btoc.

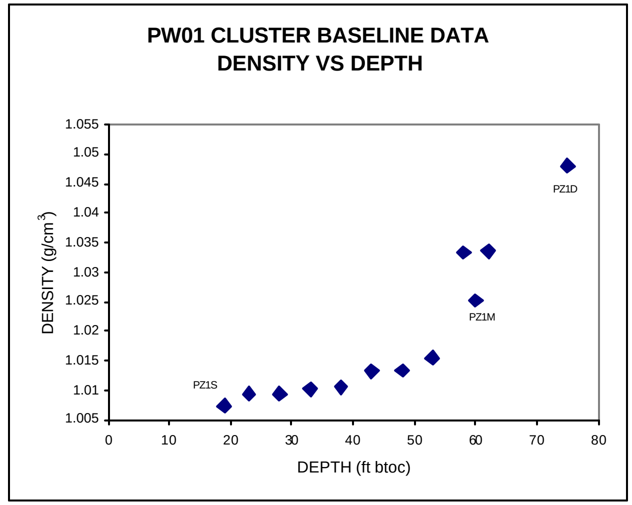
Figure 5 summarizes the lithology and baseline data collected from the well PW01 cluster. Figures 6 and 7 present a number of plots comparing specific conductance and density versus depth, specific conductance versus density and TDS, ammonia and uranium versus depth, and the sulfate/chloride ratio versus depth and TDS. These plots include data collected from each of the wells in the cluster. The sample points representing the data collected from the observation wells are labeled; the unlabeled data points represent samples collected from PW01.

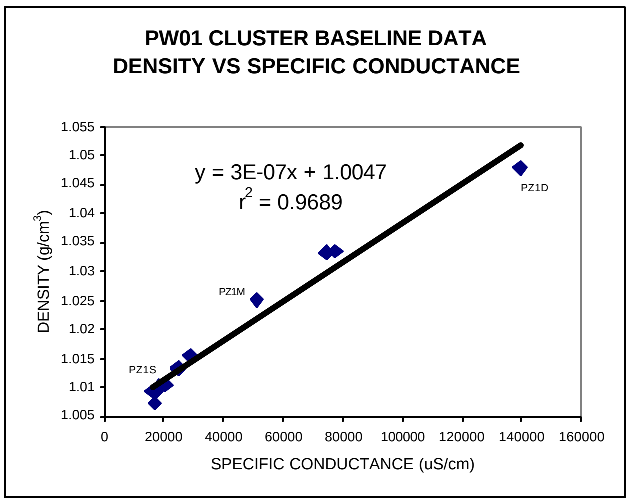


WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PZ1S	19	16931	1.0074	12325	480	1.345	1443	7338
PW01	23	17358	1.0095	12400	500	1.224	1448	7325
PW01	28	16133	1.0094	12100	490	1.204	1425	7167
PW01	33	18522	1.0102	13525	770	1.762	1391	8775
PW01	38	20459	1.0106	15113	860	2.117	1447	10147
PW01	43	24789	1.0133	18120	860	2.512	1599	11905
PW01	48	24884	1.0134	18540	840	2.505	1615	11844
PW01	53	28997	1.0155	20580	980	2.867	2147	13348
PW01	58	74545	1.0333	46100	1620	3.064	16518	14569
PZ1M	60	51293	1.0252	34433	1500	3.613	8768	15676
PW01	62	77645	1.0336	46350	1560	2.974	16998	14510
PZ1D	75	139512	1.048	77600	2350	1.053	46772	8759

Figure 5. Summary of Baseline Laboratory Data From Well PW01 Cluster







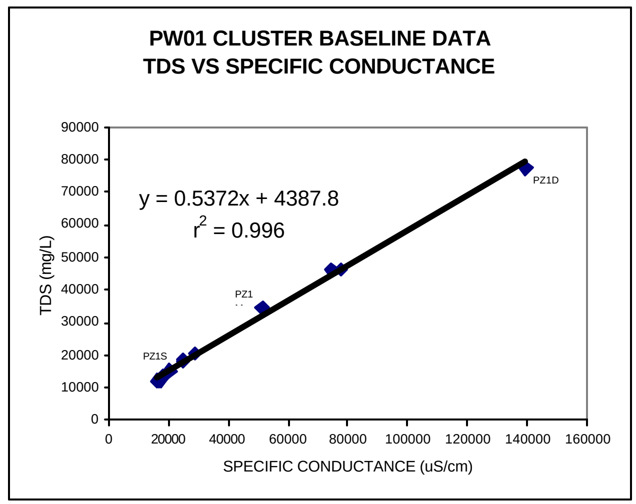


Figure 6. PW01 Cluster: Specific Conductance vs. Depth, Density vs. Depth, Density vs. Specific Conductance, and TDS vs. Specific Conductance

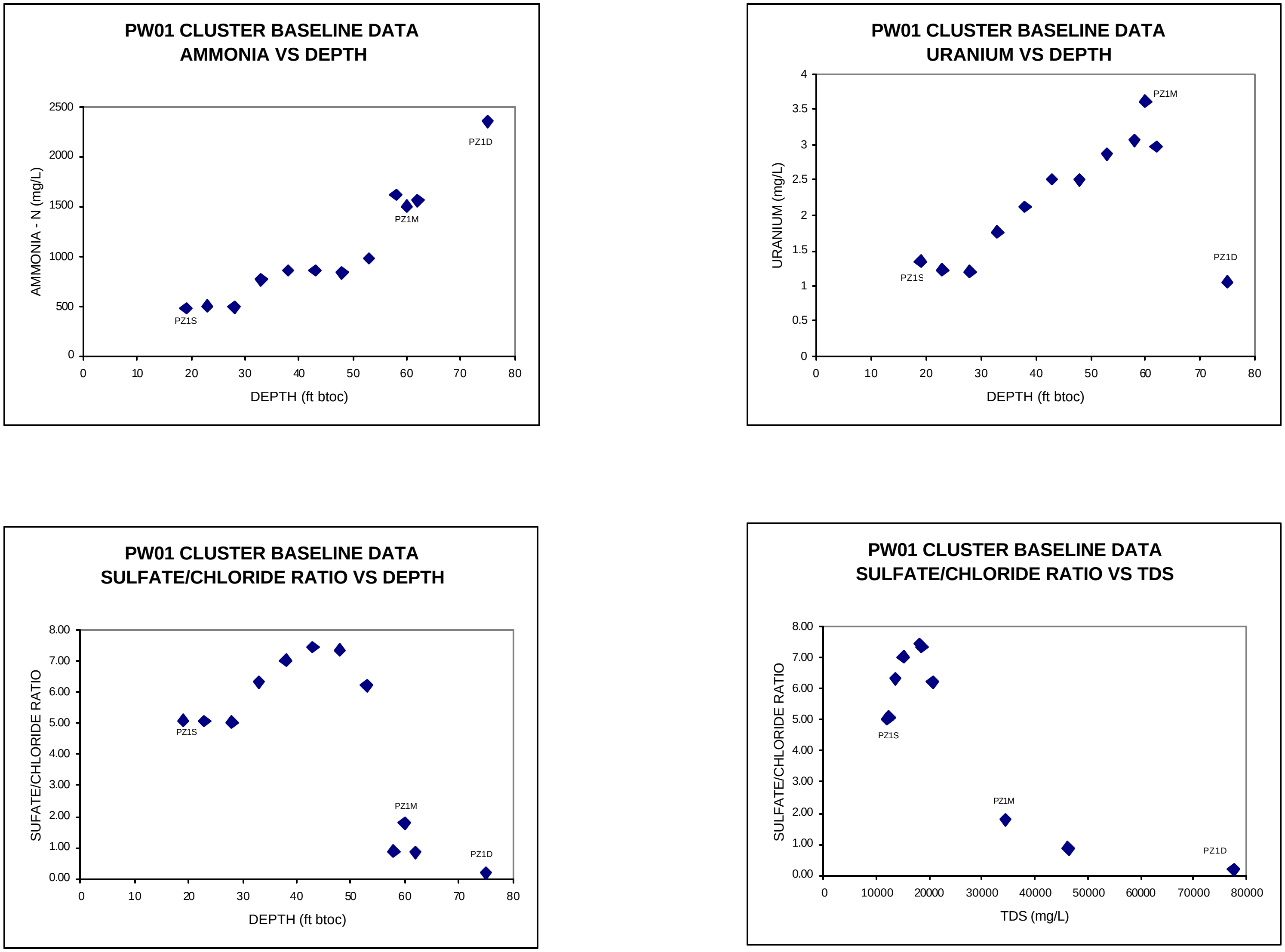


Figure 7. PW01 Cluster: Ammonia vs. Depth, Uranium vs. Depth, Sulfate/Chloride Ratio vs. Depth, and Sulfate/Chloride Ratio vs. TDS

The plots presenting the specific conductance and density versus depth are very similar; both show a gradual increase from approximately 20 ft to 55 ft btoc. Specific conductance measurements range from 16,133 to 28,997 µS/cm over these depths, and the density increases from 1.0074 to 1.0155 grams per cubic centimeter (g/cm^3). At a depth of 58 ft btoc the specific conductance and density increase sharply to 74,545 µS/cm and 1.0333 g/cm^3, respectively. The sample collected from well PZ1D has a specific conductance of 139,512 µS/cm and a density of 1.048 g/cm^3. The specific conductance versus density and specific conductance versus TDS plots display strong linear relationships, with r^2 values of 0.970 and 0.996, respectively.

Ammonia concentrations vary little from approximately 20 to 30 ft btoc (ranging from 480 to 500 mg/L), at which point the concentration increases and tends to level out again down to a depth of approximately 55 ft btoc (up to 980 mg/L). From 55 to 75 ft btoc, ammonia concentrations increase steadily from 1,500 to 2,350 mg/L.

Uranium concentrations from approximately 20 to 30 ft btoc range from 1.204 to 1.345 mg/L and increase steadily from 30 to 60 ft btoc (1.762 to 3.613 mg/L). The uranium concentration drops sharply at depths below 60 ft btoc; the sample collected from well PZ1D (collected at 75 ft btoc) had 1.053 mg/L, which is the lowest uranium concentration measured at this location.

The sulfate to chloride ratio was also used to analyze the data and segregate the water types at each location. This ratio plotted versus the sample depth reveals two distinct water types present at the PW01 cluster location, with a distinct break between 53 and 58 ft btoc. The data suggests there is no linear relationship between the sulfate/chloride ratio and the TDS concentration.

5.2 PW02 Cluster

Sampling at the PW02 cluster was completed on February 13, 2002. Table 4 lists initial water levels along with other pertinent well data. Figure 3 presents a map view and cross section of the PW02 well cluster.

Table 4. PW02 Well Cluster Data and Static Water Levels

Well	Screen Interval (ft bgs)	2/13/02 Depth to Water (ft btoc)	2/13/02 Groundwater Elevation (ft MSL)
PW02	20.0 – 60.5	13.32	3,954.16
PZ2M1	55.5 – 60.3	14.45	3,953.05
PZ2M2	55.1 – 60.4	13.93	3,953.25
PZ2D	73.2 – 78.5	14.78	3,952.60

bgs = below ground surface; btoc = below top of casing; ft = feet; MSL = mean sea level

Table 5 presents the results from the baseline sampling. Included in this table are depths at which the samples were collected and the sample temperature and pH at the time the sample was collected. In addition, this table provides the sample temperature at time of analysis and the corresponding sample density, conductivity, and specific conductance. Table 5 also includes results for NH_3 as N, Cl, SO_4, U, and TDS.

Using the Hanshaw and Hill (1969) criteria that a brine is representative of TDS concentrations greater than 35,000 mg/L, the brine zone surface at the PW02 location is measured between 48 and 53 ft btoc.

Table 5. PW02 Baseline Sampling Results

Well	Depth (ft btoc)	Field		Laboratory				Analytes (mg/L)				
		pH	T	T	Cond	SC	Density	NH_3	Cl	SO_4	U	TDS
PW02	23	6.63	15.5	20.9	25,620	27,797	1.0146	1,000	2,466	11,709	4.332	19,300
PW02	28	6.64	15.6	20.6	25,800	28,167	1.0154	1,040	2,402	12,012	4.395	19,312
PW02	33	6.64	15.6	20.6	26,480	28,910	1.0155	1,080	2,355	12,070	4.466	19,475
PW02	38	6.61	15.1	20.8	34,180	37,161	1.0172	920	7,874	8,827	3.064	23,360
PW02	43	6.63	15.5	20.5	38,360	41,967	1.0183	880	10,210	7,634	2.549	24,840
PW02	48	6.63	15.4	20.4	39,720	43,546	1.0185	900	10,438	7,612	2.488	25,420
PW02	53	6.48	15.5	20.4	74,160	81,303	1.0361	3,050	19,904	12,947	2.246	45,750
PW02	58	6.39	15.3	20.6	112,880	123,237	1.0482	4,400	39,476	11,024	1.826	62,950
PZ2M1	58	6.46	15.1	20.8	119,800	130,249	1.0493	4,300	40,785	10,538	1.682	65,100
PZ2M2	58	6.38	15.2	20.6	114,300	124,787	1.0472	4,600	37,186	11,308	1.814	60,850
PZ2D	77	6.55	15.7	20.5	139,200	152,289	1.0618	1,150	53,124	6,672	0.595	88,600

Notes: Depth measured as ft below top of casing; All temperature data measured as ^{0}C; Density measured as g/cm^3
Cond = conductivity (µS/cm); SC = specific conductance (µS/cm)

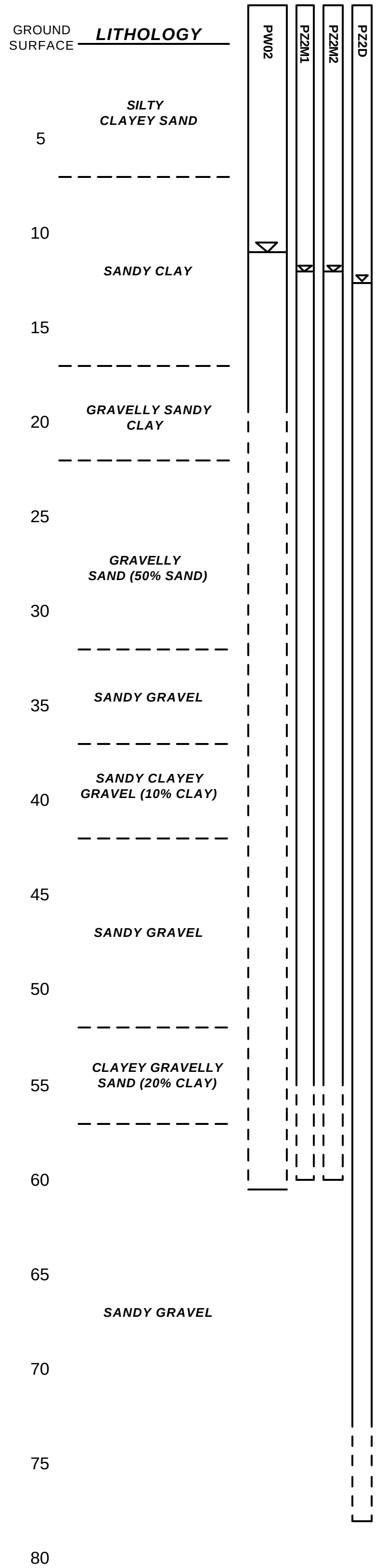
Figure 8 summarizes the lithology and baseline data collected from the well PW02 cluster. Figures 9 and 10 present the plots comparing specific conductance and density versus depth, specific conductance versus density and TDS, ammonia and uranium versus depth, and the sulfate/chloride ratio versus depth and TDS. These plots include data collected from each of the wells from the cluster. The sample points representing the data collected from the observation wells are labeled; the unlabeled data points represent samples collected from PW02.

The PW02 plots presenting the specific conductance versus depth and density versus depth are very similar to the plots of PW01 cluster data. The values increase slightly from approximately 20 ft to 50 ft btoc, where the specific conductance measurements ranged from 27,797 to 43,546 µS/cm and the density ranged from 1.0146 to 1.0185 g/cm^3. Between 50 and 77 ft, the specific conductance and density increase sharply to 152,289 µS/cm and 1.0618 g/cm^3, respectively. The specific conductance versus density and specific conductance versus TDS plots display strong linear relationships, with r^2 values of 0.992 and 0.978, respectively.

Ammonia concentrations vary little from approximately 20 to 50 ft btoc (ranging from 880 to 1,080 mg/L), at which point the concentration increase sharply and reaches 4,600 mg/L at a depth of 58 ft btoc. From this point, the concentration drops to 1,150 mg/L at a depth of 77 ft btoc.

Uranium concentrations are highest in the shallow depths and decrease with depth after approximately 35 ft btoc. From 20 to 35 ft btoc, uranium concentrations range from 4.332 to 4.466 mg/L. The sample collected from 38 ft btoc contained 3.064 mg/L, and the concentration gradually decreased to 0.595 mg/L in the sample collected from PZ2D at 77 ft btoc.

The sulfate/chloride ratio plotted versus the sample depth for the PW02 also includes data collected from the Sandbar Area study completed during November/December 2001. These data are presented in the ESL sandbar report (DOE 2002b), which includes data collected from BH-08, 401, and 408 (all of which are located next to each other 350 ft northeast of the PW01 location, adjacent to the river). As shown in Figure 10, the data collected from the previous study correspond well with the Sandbar Area data. As with the PW01 cluster, the data suggest two distinct water types, with a distinct break between 33 and 38 ft btoc.



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PW02	23	27797	1.0146	19300	1000	4.332	2466	11709
PW02	28	28167	1.0154	19312	1040	4.395	2402	12012
PW02	33	28910	1.0155	19475	1080	4.466	2355	12070
PW02	38	37161	1.0172	23360	920	3.064	7874	8827
PW02	43	41967	1.0183	24840	880	2.549	10210	7634
PW02	48	43546	1.0185	25420	900	2.488	10438	7612
PW02	53	81303	1.0361	45750	3050	2.246	19904	12947
PW02	58	123237	1.0482	62950	4400	1.826	39476	11024
PZ2M1	58	130249	1.0493	65100	4300	1.682	40785	10538
PZ2M2	58	124787	1.0472	60850	4600	1.814	37186	11308
PZ2D	77	152289	1.0618	88600	1150	0.595	53124	6672

Figure 8. Summary of Baseline Laboratory Data From Well PW02 Cluster

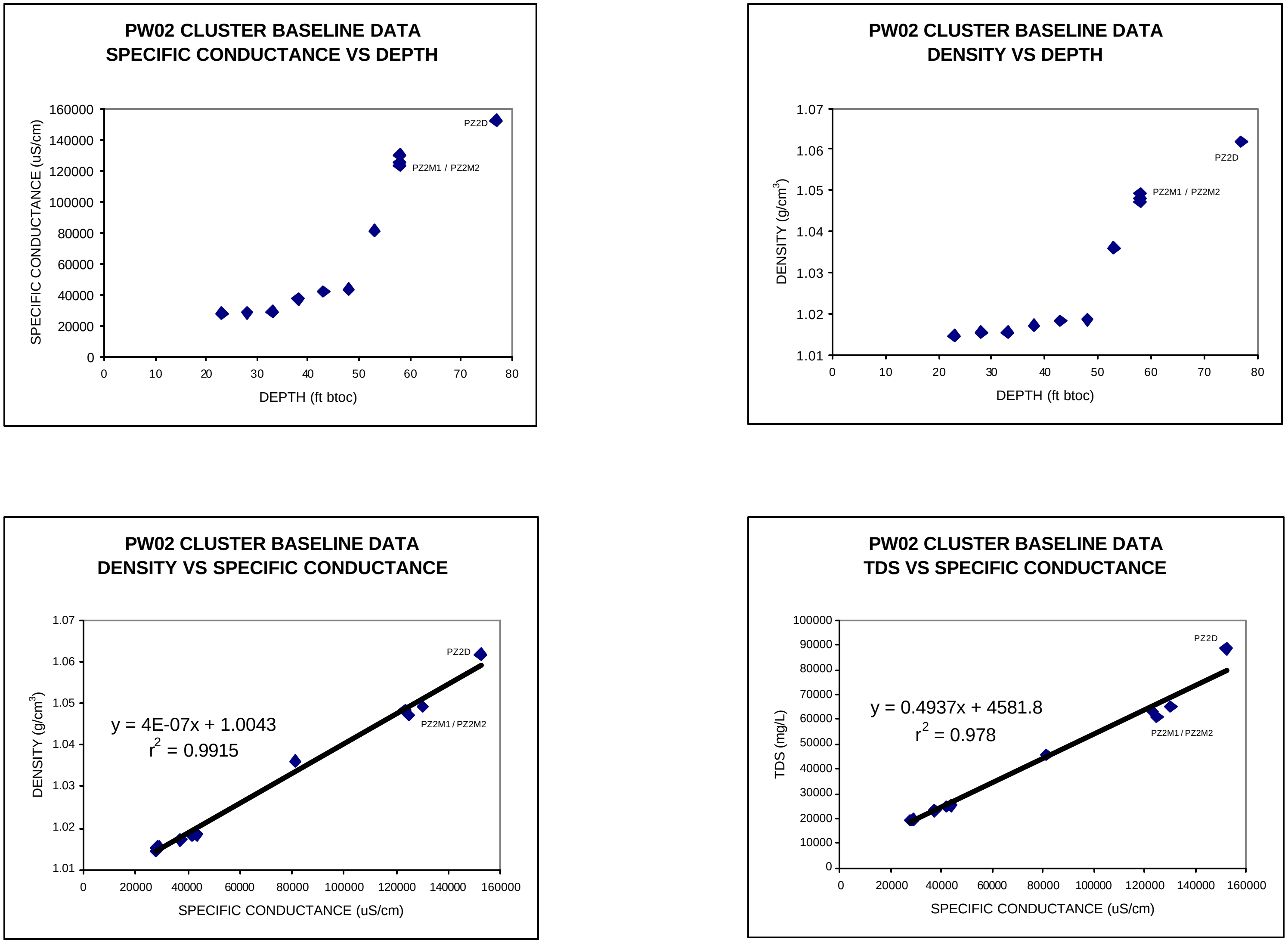


Figure 9. PW02 Cluster: Specific Conductance vs. Depth, Density vs. Depth, Density vs. Specific Conductance, and TDS vs. Specific Conductance

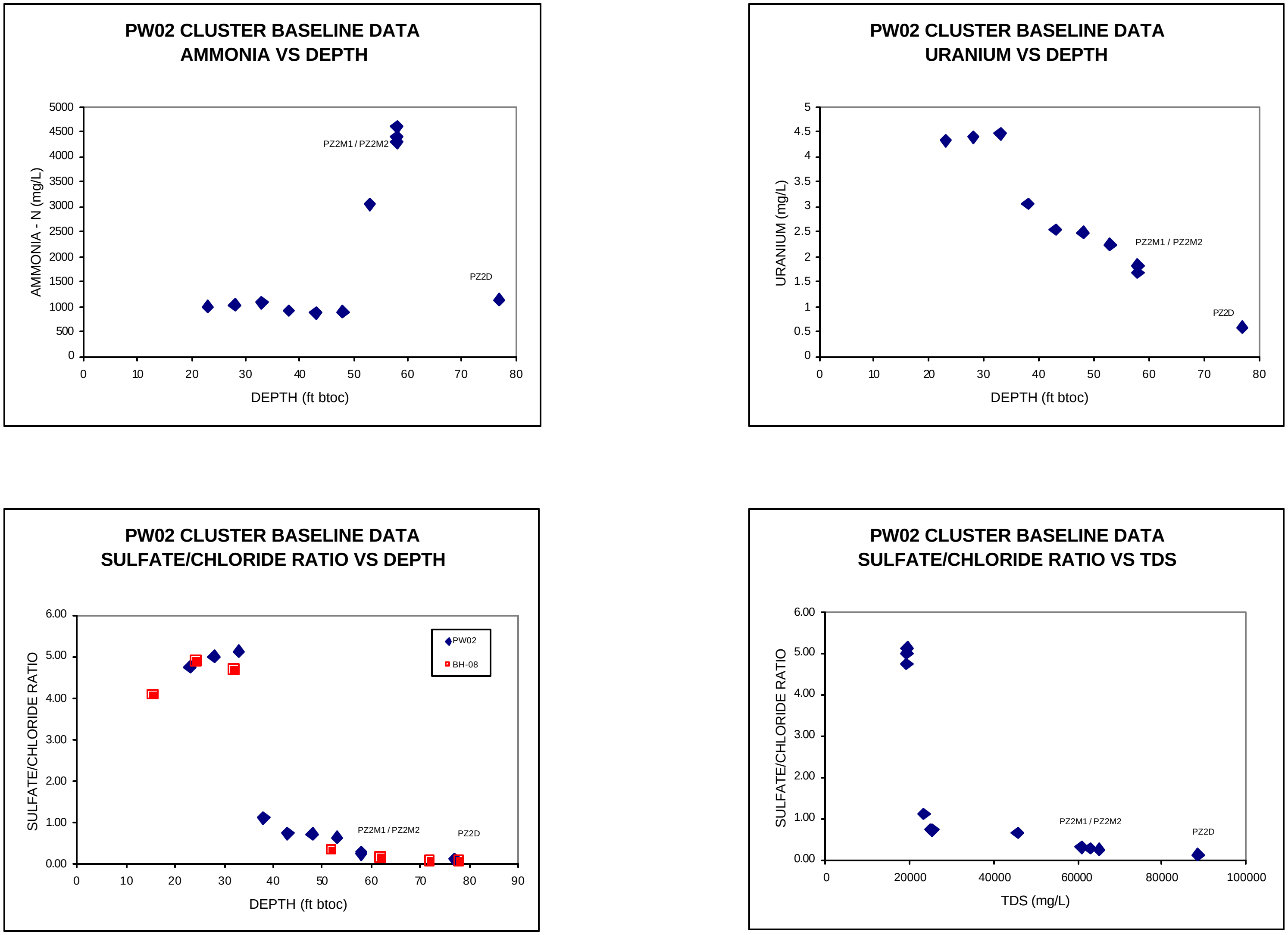


Figure 10. PW02 Cluster: Ammonia vs. Depth, Uranium vs. Depth, Sulfate/Chloride Ratio vs. Depth, and TDS vs. Sulfate/Chloride Ratio

A plot of the sulfate/chloride ratio versus the TDS does not show a linear relationship between these components.

5.3 PW03 Cluster

Sampling at the PW03 cluster was completed on February 12, 2002. Table 6 lists the initial water levels are listed in Table 6 along with other pertinent well data. Figure 4 presents a map view and cross section of the PW03 well cluster.

Table 6. PW03 Well Cluster Data and Static Water Levels

Well	Screen Interval (ft bgs)	2/13/02 Depth to Water (ft btoc)	2/13/02 Groundwater Elevation (ft MSL)
PW03	20.2 – 60.5	18.67	3,956.37
PZ3S	21.9 – 27.2	18.72	3,956.31
PZ3M	54.8 – 60.1	18.85	3,956.38
PZ3D2	75.3 – 80.6	19.14	3,955.99

bgs = below ground surface; btoc = below top of casing; ft = feet; MSL = mean sea level

Table 7 presents the results from the baseline sampling. Included in this table are depths at which the samples were collected, and the sample temperature and pH at the time the sample was collected. In addition, this table provides the sample temperature at time of analysis and the corresponding sample density, conductivity, and specific conductance. Table 7 also includes results for NH_3 as N, Cl, SO_4, U, and TDS.

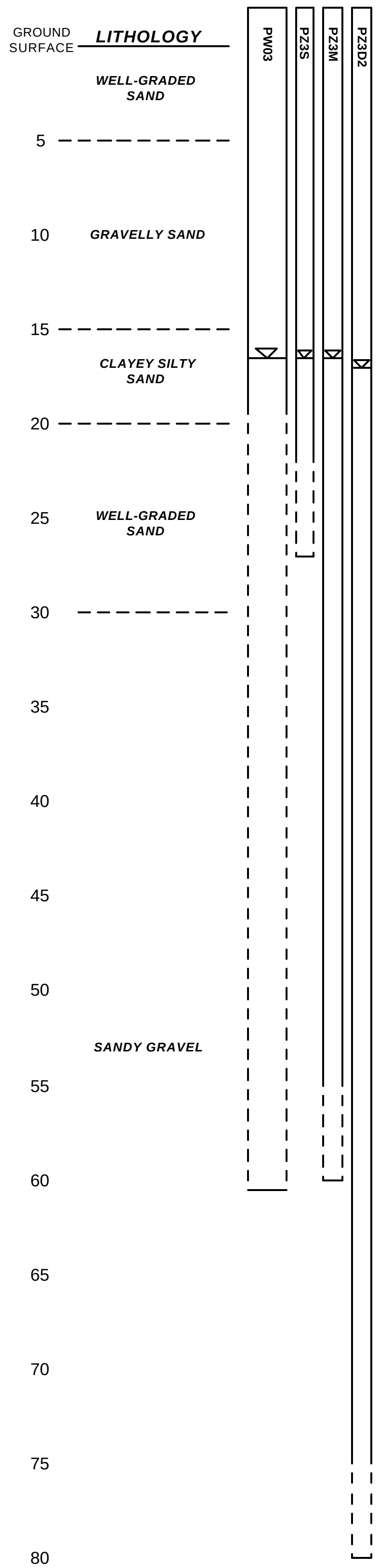
Table 7. PW03 Baseline Sampling Results

Well	Depth (ft btoc)	Field		Laboratory				Analytes (mg/L)				
		pH	T	T	Cond	SC	Density	NH_3	Cl	SO_4	U	TDS
PW03	23	7.35	16.4	22.4	8750	9207	1.0036	37	1765	1896	1.755	5960
PW03	28	7.27	15.8	21	9060	9809	1.0039	40	1951	1947	1.052	6240
PW03	33	7.29	16.6	20.7	9210	10034	1.0037	41	1965	1941	0.960	6227
PW03	38	7.28	16.6	21.3	9230	9932	1.0030	40	1970	1942	1.049	6253
PW03	43	7.28	16.9	21.9	9280	9864	1.0034	35	1941	1954	0.974	6287
PW03	48	7.27	16.8	22.1	9360	9909	1.0039	35	1959	1989	1.004	6400
PW03	53	7.27	16.9	21.3	9550	10276	1.0035	30	1997	2072	1.030	6507
PW03	58	7.25	17.1	21	9940	10762	1.0034	35	2035	2261	1.174	6880
PW03	61	7.18	16.9	21.8	10820	11524	1.0050	53	2149	2712	1.508	7640
PZ3S	25	7.8	17.4	21.8	5420	5773	1.0026	5	877	1156	3.036	3550
PZ3M	58	7.32	17.1	20.9	9240	10025	1.0030	38	1994	1939	0.994	6107
PZ3D2	78	6.80	16.5	21.5	25240	27048	1.0160	540	3292	10709	3.001	19175

Cond = conductivity (µS/cm); SC = specific conductance (µS/cm)
Notes: Depth measured as ft below top of casing; All temperature data measured as ^{o}C; Density measured as g/cm^3

According to Hanshaw and Hill (1969) the data indicate a true brine zone was not encountered at this location. However, an increase in TDS concentrations was detected in the sample collected at a depth of 78 ft btoc, suggesting the presence of the brine zone surface at a deeper elevation.

Figure 11 summarizes the lithology and baseline data collected from the well PW03 cluster. Figures 12 and 13 present the plots of specific conductance and density versus depth, specific conductance versus density and TDS, ammonia and uranium versus depth, and the sulfate/chloride ratio versus depth and TDS. These plots include data collected from each of the wells in the cluster. The sample points representing the data collected from the observation wells are labeled; the unlabeled data points represent samples collected from PW03.



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm³)	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PW03	23	9207	1.0036	5960	37	1.755	1765	1896
PZ3S	25	5773	1.0026	3550	5	3.036	877	1156
PW03	28	9809	1.0039	6240	40	1.052	1951	1947
PW03	33	10034	1.0037	6227	41	0.960	1965	1941
PW03	38	9932	1.003	6253	40	1.049	1970	1942
PW03	43	9864	1.0034	6287	35	0.974	1941	1954
PW03	48	9909	1.0039	6400	35	1.004	1959	1989
PW03	53	10276	1.0035	6507	30	1.030	1997	2072
PW03	58	10762	1.0034	6880	35	1.174	2035	2261
PZ3M	58	10025	1.003	6107	38	0.994	1994	1939
PW03	61	11524	1.005	7640	53	1.508	2149	2712
PZ3D2	78	27048	1.016	19175	540	3.001	3292	10709

Figure 11. Summary of Baseline Laboratory Data From Well PW03 Cluster

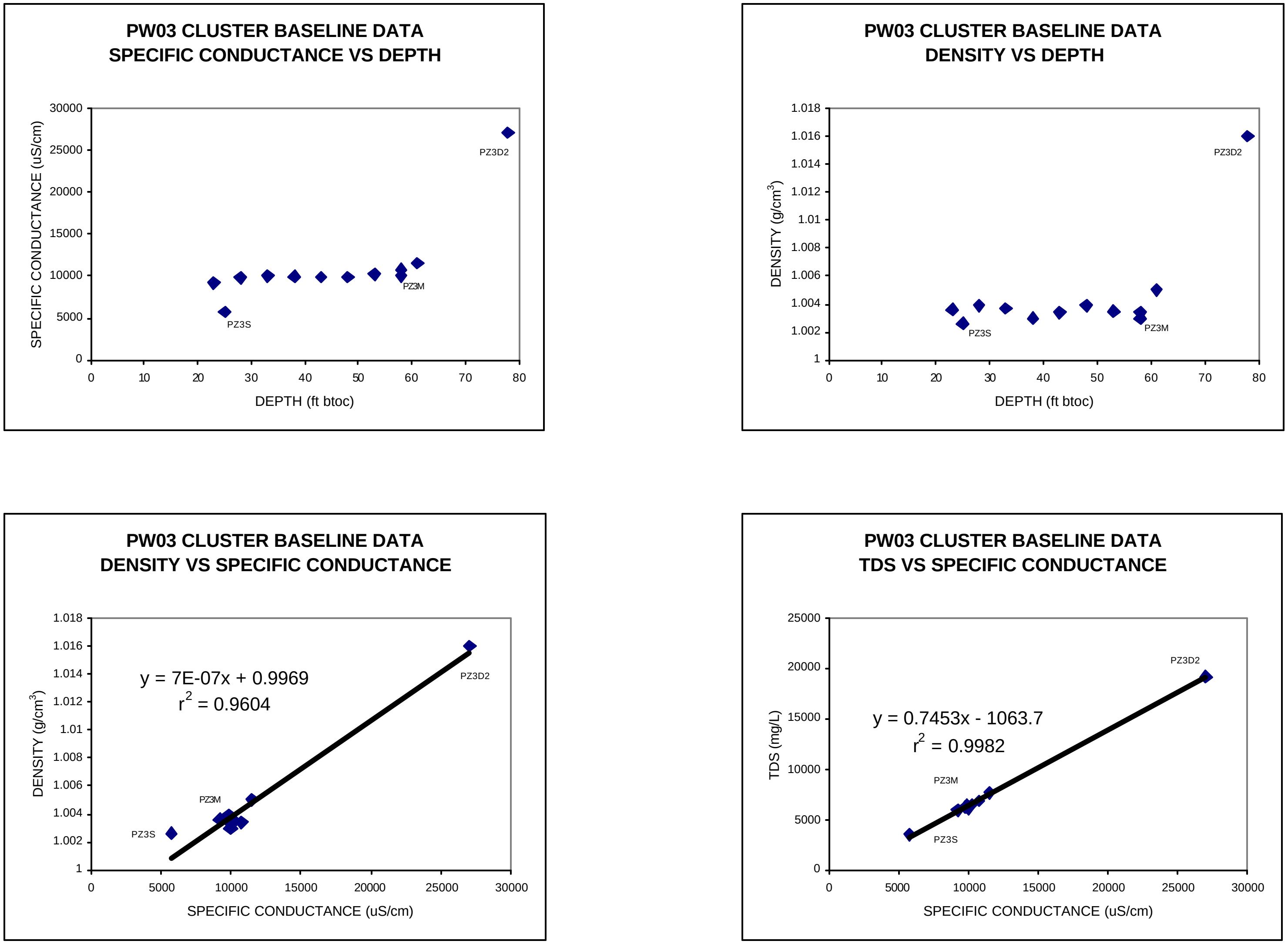


Figure 12. PW03 Cluster: Specific Conductance vs. Depth, Density vs. Depth, Specific Conductance vs. Density, and Specific Conductance vs. TDS

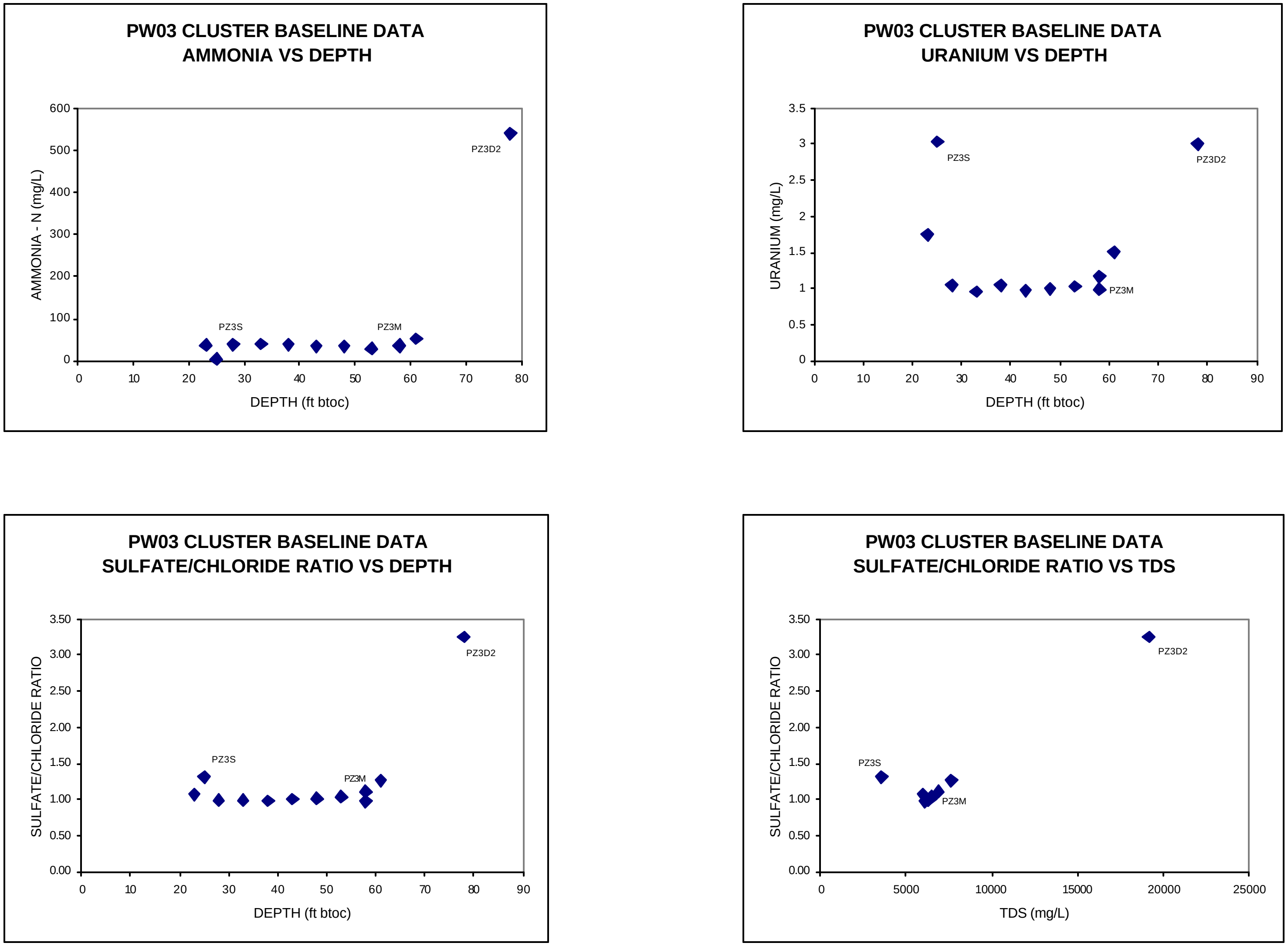


Figure 13. PW03 Cluster: Ammonia vs. Depth, Uranium vs. Depth, Sulfate/Chloride Ratio vs. Depth, and Sulfate/Chloride Ratio vs. TDS

The PW03 plots presenting the specific conductance versus depth and density versus depth again are similar. Excluding the sample collected from PZ3S (which had a specific conductance of 5,773 µS/cm and a density of 1.0026 g/cm^3), there is essentially no change from approximately 20 to 60 ft bgs, where the specific conductance ranges from 9,207 to 11,524 µS/cm, and the density ranges from 1.0036 to 1.005 g/cm^3. The sample collected from PZ3D2 at a depth of 78 ft btoc had a specific conductance measurement of 27,048 µS/cm and a density of 1.016 g/cm^3. The specific conductance versus density and specific conductance versus TDS plots display strong linear relationships, with r^2 values of 0.960 and 0.998, respectively.

Ammonia concentrations versus depth exhibited the same pattern as that of the specific conductance and density versus depth. Again, excluding the concentration measured from well PZ3S (which had an ammonia concentration of 5 mg/L), ammonia concentrations are very consistent, ranging from 37 to 53 mg/L. The sample collected from well PZ3D2 at 78 ft btoc contained 540 mg/L ammonia.

Uranium concentrations are highest in the shallowest and deepest sampling depth. The sample collected from well PZ3S contained 3.036 mg/L, and the samples collected from PW03 at 23 ft btoc contained 1.755 mg/L. Concentrations remain fairly constant between depths of 28 and 58 ft btoc and range from 0.960 and 1.174 mg/L in that interval. At increasing depths, the concentration peaks at 3.001 mg/L in the sample collected from PZ3D2 at 78 ft btoc.

The sulfate/chloride ratio versus depth plot shows the shallow water at this location contains a low sulfate/chloride ratio (all less than 1.5), and the sample collected from observation well PZ3D2 contains the only ratio greater than 3.0 within this sample group. This trend is opposite of that displayed by the PW01 and PW02 locations, in which the shallowest water contained the highest sulfate/chloride ratios. These data from PW03 also suggest the pumping well contains only one water type, and only observation well PZ3D2 (which is screened over a deeper part of the aquifer than the pumping well) contains a different water type.

6.0 Results—Aquifer Tests

The Work Plan (DOE 2002a) discussed plans to perform tests at each of the three well cluster locations. After analysis of the baseline sampling data, it became evident that the PW01 cluster was the best location to complete the aquifer tests. The PW02 cluster does not include an observation well completed in the aquifer shallow zone, and the pumping well at the PW03 cluster did not provide enough groundwater vertical variation between the brine and freshwater zones (i.e., the brine zone was identified only in the deepest completed observation well PZ3D).

As a result, three different tests were completed at the PW01 cluster using various pumping rates and pump intake depths. Each test is discussed separately, starting with the water chemistry sampling results and followed by the water level response to pumping.

6.1 Pumping at 5 and 15 gpm With the Pump Intake Set at 25 ft btoc

6.1.1 Water Chemistry Results

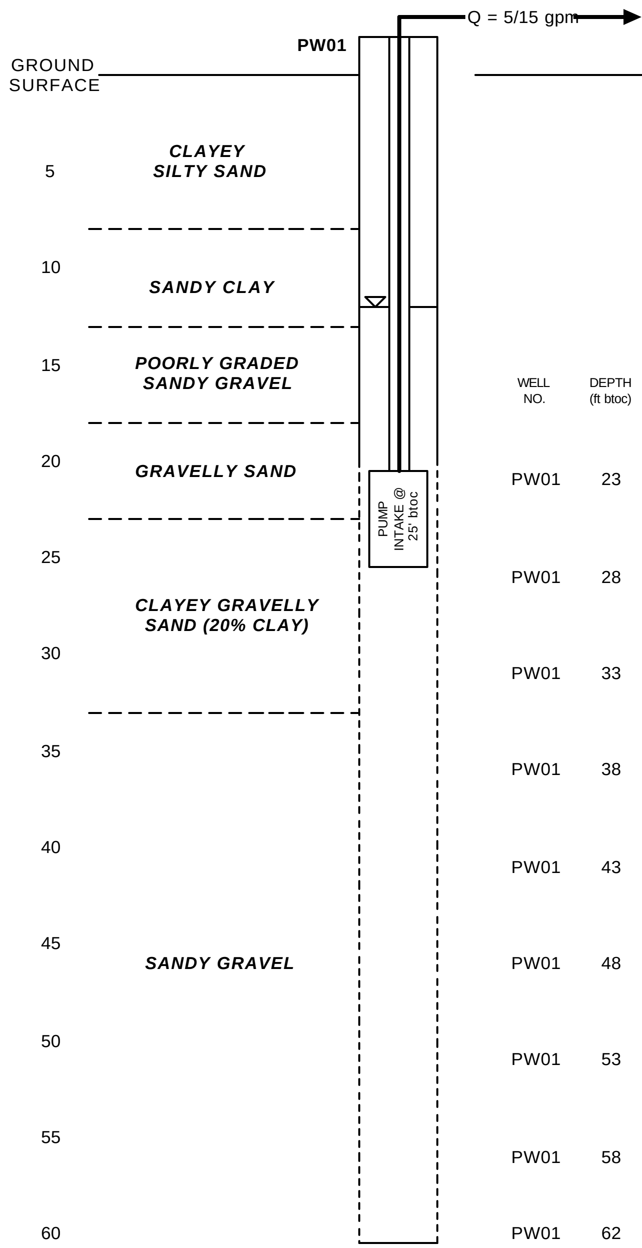
The first test to be discussed was started at 16:15 on March 11, 2002, at a pumping rate of only 5 gallons per minute (gpm). A submersible pump was used for this test, with its intake set at a depth of 25 ft btoc. After 16 hours (h) and 45 min, the pumping rate was increased to 15 gpm. After 25 h of pumping at 15 gpm, the pump was shut off and a recovery test was started. Figure 14 provides the location of the pump intake in relation to the lithology and the baseline sampling results.

A number of samples were collected at various times during both the pumping and recovery phase of this test. Sample times and results from the pumping phase are included in Table 8. Appendix B contains a plot of the specific conductance data collected by the Troll 8000 probes. The specific conductance data obtained from the samples collected for laboratory analysis (Table 8) provide more accurate values, and the data collected by the Troll 8000 units provide the specific conductance trend during the test period.

Figure 15 is a plot of the specific conductance data during the test interval. As the figure shows, pumping caused brine to flow into the pumping well. The specific conductance more than doubled from approximately 15,500 :S/cm to over 33,000 :S/cm almost instantaneously after the pump was started at only 5 gpm. After more than 16 h of pumping at the same rate, the specific conductance remained over 29,000 :S/cm. Once the pumping rate was increased to 15 gpm, the specific conductance of the discharge water again almost instantly increased to about 49,000 :S/cm, and hit a maximum of approximately 58,500 :S/cm after 85 min of pumping at the increased rate. Over the 25-h time interval of pumping at a rate of 15 gpm, the specific conductance of the discharge water did not drop below the 55,000 :S/cm level.

There was no response detected in the shallow observation well, PZ1S. However, the middle observation well, PZ1M (which is screened over approximately the same elevation as the bottom 5 ft of the pumping well) did show a response to pumping. There was a slight increase immediately after the test was started, from approximately 45,000 to over 51,000 :S/cm.

PW01
Q = 5/15 gpm
INTAKE SET 25 ft btoc



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PW01	23	17358	1.0095	12400	500	1.224	1448	7325
PW01	28	16133	1.0094	12100	490	1.204	1425	7167
PW01	33	18522	1.0102	13525	770	1.762	1391	8775
PW01	38	20459	1.0106	15113	860	2.117	1447	10147
PW01	43	24789	1.0133	18120	860	2.512	1599	11905
PW01	48	24884	1.0134	18540	840	2.505	1615	11844
PW01	53	28997	1.0155	20580	980	2.867	2147	13348
PW01	58	74545	1.0333	46100	1620	3.064	16518	14569
PW01	62	77645	1.0336	46350	1560	2.974	16998	14510

Figure 14. PW01: Q= 5/15 gpm Test Scenario

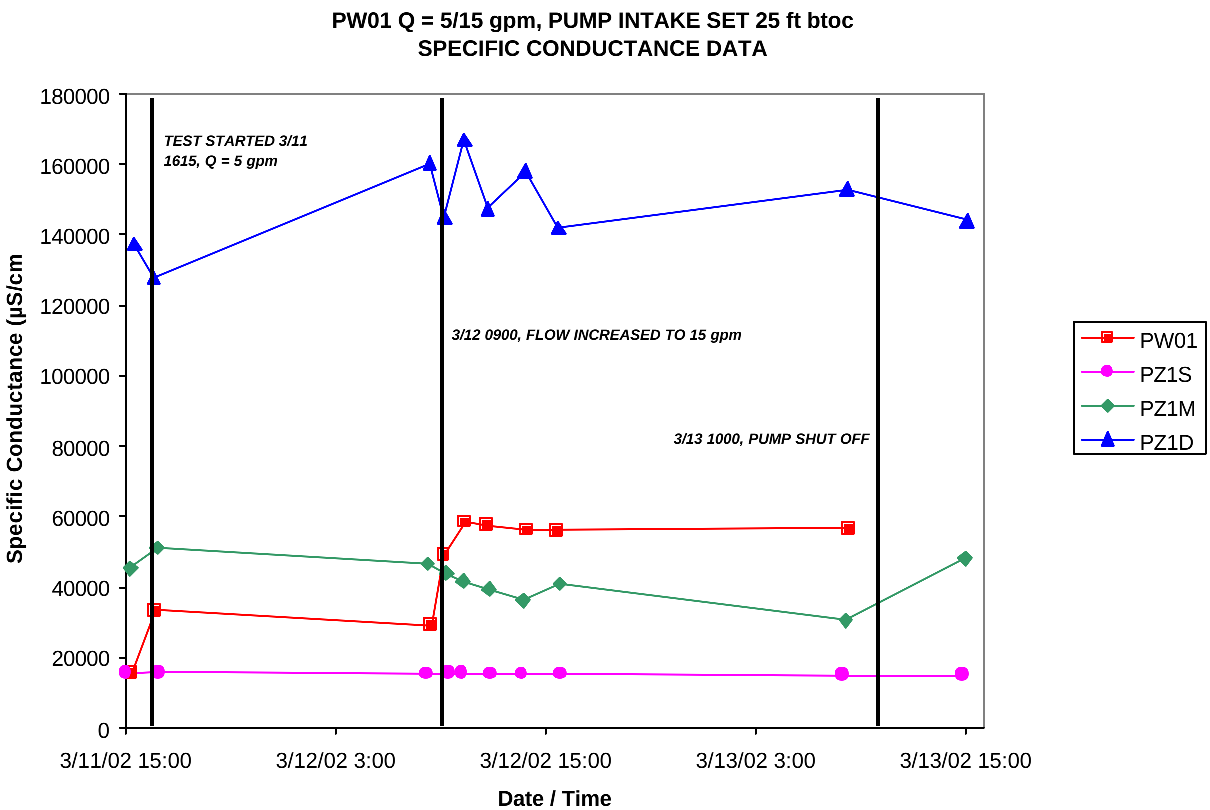


Figure 15. PW01: Q = 5/15 gpm—Test Specific Conductance vs. Time

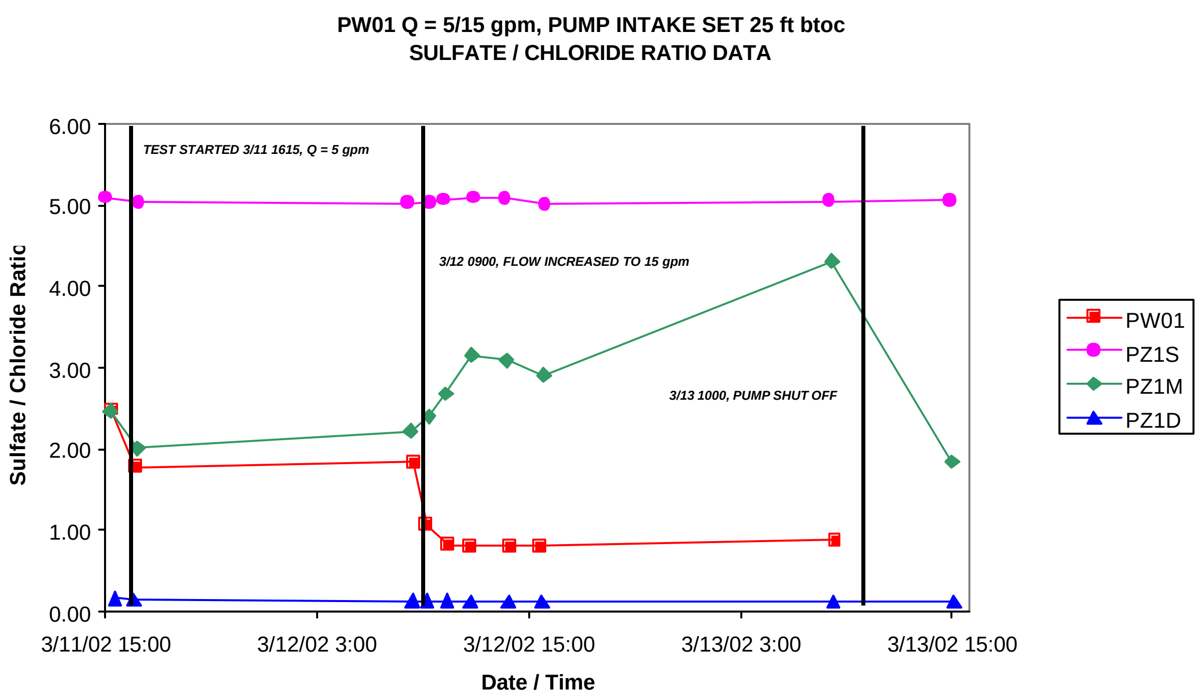


Figure 16. PW01: Q = 5/15 gpm—Test Sulfate/Chloride vs. Time

Table 8. Sample Results From Q = 5/15 gpm Test Pumping Phase

Well	Depth (ft btoc)	Date/Time	T (°C)	Cond (:S/cm)	SC (:S/cm)	Density (g/cm^3)	NH_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)	TDS (mg/L)
PW01	25	3/11/02 15:20	22.6	14,820	15,532	1.0094	520	2,822	7,018	1.277	11,867
PW01	25	3/11/02 16:41	22.6	31,700	33,223	1.0161	820	5,323	9,482	1.963	20,012
PW01	25	3/12/02 8:27	22.8	27,900	29,124	1.0146	780	5,044	9,263	1.951	19,025
PW01	25	3/12/02 9:10	22.7	46,800	48,950	1.0227	1,120	10,141	10,837	2.343	30,025
PW01	25	3/12/02 10:25	22.6	55,850	58,533	1.0238	1,240	12,210	10,016	2.085	32,300
PW01	25	3/12/02 11:38	22.7	55,100	57,632	1.0245	1,180	12,551	10,118	2.095	32,675
PW01	25	3/12/02 13:54	23.1	54,150	56,189	1.0249	1,120	12,477	10,040	2.007	32,325
PW01	25	3/12/02 15:38	23.5	54,350	55,953	1.0245	1,340	12,634	10,180	2.037	32,750
PW01	25	3/13/02 8:21	23.5	54,950	56,571	1.0247	1,160	11,179	9,873	2.194	32,100
PZ1S	19	3/11/02 15:00	23.5	15,070	15,514	1.0093	480	1,396	7,106	1.294	11,900
PZ1S	19	3/11/02 16:53	23.5	15,170	15,617	1.0089	520	1,430	7,198	1.319	11,833
PZ1S	19	3/12/02 8:10	23.4	14,830	15,297	1.0085	500	1,369	6,880	1.412	12,089
PZ1S	19	3/12/02 9:26	23.9	15,140	15,465	1.0093	500	1,414	7,121	1.363	11,889
PZ1S	19	3/12/02 10:12	24.1	15,160	15,425	1.0096	460	1,367	6,926	1.350	12,033
PZ1S	19	3/12/02 11:52	24.3	15,160	15,365	1.0093	520	1,418	7,218	1.372	12,022
PZ1S	19	3/12/02 13:38	24.3	15,150	15,355	1.0088	480	1,415	7,185	1.360	11,989
PZ1S	19	3/12/02 15:54	24.3	15,140	15,345	1.0085	480	1,383	6,932	1.348	11,900
PZ1S	19	3/13/02 8:01	25.6	15,160	14,988	1.0079	500	1,379	6,969	1.368	12,056
PZ1S	19	3/13/02 14:51	25.4	15,130	15,015	1.0073	500	1,413	7,143	1.292	11,922
PZ1M	60	3/11/02 15:15	23.6	44,000	45,209	1.0257	1,300	6,103	15,053	3.624	29,350
PZ1M	60	3/11/02 16:47	23.3	49,500	51,161	1.0276	1,480	7,816	15,675	3.738	32,800
PZ1M	60	3/12/02 8:16	24.2	45,850	46,561	1.0261	1,440	7,100	15,753	3.712	30,980
PZ1M	60	3/12/02 9:19	24.1	43,000	43,752	1.0247	1,420	6,415	15,407	3.663	29,800
PZ1M	60	3/12/02 10:17	24.6	41,400	41,719	1.0233	1,280	5,487	14,695	3.542	28,500
PZ1M	60	3/12/02 11:46	23.6	38,250	39,301	1.0210	1,220	4,784	15,108	3.339	25,420
PZ1M	60	3/12/02 13:43	24.2	35,650	36,203	1.0212	1,160	4,566	14,116	3.252	25,580
PZ1M	60	3/12/02 15:49	24.1	40,100	40,801	1.0217	1,200	4,912	14,296	3.378	25,860
PZ1M	60	3/13/02 8:09	25.2	30,650	30,533	1.0170	940	2,978	12,831	3.054	21,300
PZ1M	60	3/13/02 15:00	25	48,200	48,200	1.0263	1,380	8,317	15,310	3.576	32,340
PZ1D	75	3/11/02 15:30	24.9	137,200	137,463	1.0561	1,600	45,868	7,594	0.826	80,300
PZ1D	75	3/11/02 16:35	24.1	125,600	127,797	1.0577	1,480	48,705	7,110	0.638	84,700
PZ1D	75	3/12/02 8:22	23.5	155,700	160,292	1.0583	1,380	51,097	6,912	0.479	86,000
PZ1D	75	3/12/02 9:13	23.7	141,400	145,000	1.0596	1,180	51,183	6,600	0.451	87,200
PZ1D	75	3/12/02 10:21	24.3	164,700	166,932	1.0594	1,160	52,833	6,807	0.484	86,900
PZ1D	75	3/12/02 11:42	24.5	146,100	147,509	1.0598	1,000	52,835	6,739	0.390	87,800
PZ1D	75	3/12/02 13:50	24.4	156,200	158,011	1.0604	1,000	53,148	6,611	0.355	88,000
PZ1D	75	3/12/02 15:44	24.1	139,600	142,042	1.0601	940	54,958	6,739	0.428	87,500
PZ1D	75	3/13/02 8:15	24.3	150,900	152,945	1.0604	880	52,081	6,467	0.319	88,300
PZ1D	75	3/13/02 15:06	24.7	143,200	144,025	1.0608	1,100	53,434	6,820	0.452	87,200

Notes: Depth measured as ft below top of casing (ft btoc); Cond = conductivity; SC = specific conductance

After more than 16 h of pumping at 5 gpm, the specific conductance decreased to near the initial level (approximately 46,500 :S/cm). However, once the pumping rate was increased to 15 gpm, the specific conductance showed a constant decrease, eventually dropping to approximately 30,500 :S/cm, suggesting the water at this elevation was actually being diluted in some fashion.

Figure 15 also presents the data collected from deep observation well PZ1D. The plot shows a wide range of values measured during the test, from approximately 137,000 to over 160,000 :S/cm, and the fluctuations did not necessarily correspond to pumping.

Figure 16 was generated from the sulfate/chloride ratio data. In this plot, there appears to be no effect on the shallow and deep zones; however, a response was detected in PW01 and PZ1M. The sulfate/chloride ratio in PW01 drops over the test interval, and the ratio in PZ1M increases.

Figure 17 presents the uranium concentration data collected over the test period. Samples collected from PW01 show a sharp increase in uranium concentration from 1.277 to 1.963 mg/L after the test was started with a pumping rate of 5 gpm. There was a minimal increase, from 1.951 to 2.343 mg/L, after the pumping rate was increased to 15 gpm. Uranium concentrations then decreased to 2.085 mg/L after 1.5 h of pumping and did not significantly fluctuate the remainder of the test. The samples collected from PZ1S ranged from 1.294 to 1.412 mg/L uranium, showing no definitive response to the different flow rates.

Samples collected from PZ1M during the test indicate that uranium concentration increased slightly after the test was started (from 3.624 to 3.738 mg/L). Once the pumping rate was increased to 15 gpm, uranium concentration gradually decreased to 3.054 mg/L, and then sharply increased back up to 3.576 mg/L after the pump was shut off.

The samples collected from PZ1D indicate that uranium concentrations also respond to pumping. There was an initial decrease from 0.826 to 0.638 mg/L after the test was started. An increase in the flow rate to 15 gpm resulted in a gradual concentration decrease to 0.319 mg/L by the end of the test. After the pump was shut off, the uranium concentration rebounded to 0.452 mg/L.

Figure 18 shows the ammonia concentration trend over the testing period. Samples collected from PW01 show a sharp increase after the start of the test (from 520 to 820 mg/L) and after the pumping rate was increased to 15 gpm (from 780 mg/L to 1,120 mg/L). The shallow zone exhibited no response to pumping, and ammonia concentrations ranged from 460 to 520 mg/L during the test period.

Samples collected from PZ1M and PZ1D indicate these zones were affected by pumping. Ammonia concentrations in samples collected from PZ1M initially increase from 1,300 to 1,480 mg/L after the test was started, then remained constant through the 5-gpm pumping period. Once the flow rate was increased to 15 gpm, the ammonia concentrations gradually decreased to 940 mg/L before increasing to 1,380 mg/L after the pump was shut off.

With the exception of the initial increase after the test was started, ammonia concentrations in samples collected from PZ1D exhibit the same trend as the PZ1M samples. Once the test was started, the concentrations decreased from 1,600 to 1,480 mg/L. Subsequent samples showed a decreasing trend identical to that detected in the PZ1M samples. The concentration reached 880 mg/L at the end of the 15-gpm pumping period. A sharp increase was measured during the recovery phase, when ammonia concentration reached 1,100 mg/L.

During the recovery test (Table 9) vertical profile data were collected from pumping well PW01 using the Troll 8000 probe. This instrument was raised and lowered slowly up and down the length of the screen to collected data for six separate profiles. These data are presented as Figure 19. As this Figure shows, after approximately 1.5 h, there is a small amount of change regarding the rebound of the vertical specific conductance profile within the well.

Figure 20 is a plot generated from the samples collected from depths of 45 and 57 ft btoc during the recovery of PW01. These samples were collected after 0.7, 1.4, and 4.3 h of recovery. At a depth of 45 ft btoc, there appears to be a constant amount of change between the sampling periods, and at 57 ft btoc the largest amount of change occurs between 0.7 h and 1.4 h. between 1.4 and 4.3 h, there was minimal change in the specific conductance.

Table 9. Sample Results From Q = 5/15 gpm Test Recovery Phase

Well	Depth (ft btoc)	Date/Time	T (°C)	Cond (: S/cm)	SC (: S/cm)	Density (g/cm^3)	NH_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)	TDS (mg/L)
PW01	45	3/13/02 10:25	23	61,000	63,423	1.0291	1,300	14,753	11,688	2.615	39,133
PW01	45	3/13/02 10:52	23.6	28,750	29,540	1.0233	720	4,615	8,848	1.830	18,038
PW01	45	3/13/02 14:08	23.7	26,350	27,021	1.0148	720	3,573	10,583	2.467	18,275
PW01	57	3/13/02 10:12	23.5	30,950	31,863	1.0156	900	6,026	9,121	1.946	20,700
PW01	57	3/13/02 11:09	23.3	47,650	49,249	1.0223	1,120	9,749	10,509	2.320	29,575
PW01	57	3/13/02 13:54	23.1	46,400	48,147	1.0219	1,080	9,663	10,804	2.358	29,380
PZ1S	19	3/13/02 14:51	25.4	15,130	15,015	1.0073	500	1,413	7,143	1.292	11,922
PZ1M	60	3/13/02 15:00	25	48,200	48,200	1.0263	1,380	8,317	15,310	3.576	32,340
PZ1D	75	3/13/02 15:06	24.7	143,200	144,025	1.0608	1,100	53,434	6,820	0.452	87,200

Notes: Depth measured as ft below top of casing (ft btoc); Cond = conductivity; SC = specific conductance

6.1.2 Water Elevation Results

Table 10 presents the total drawdown data measured at the end of each of the pumping periods.

Table 10. Total Drawdown Measured During the Q= 5/15 gpm Test

Well	Total Drawdown after 5 gpm Step (ft)	Total Drawdown after 15 gpm Step (ft)
PW01	0.71	1.37
PZ1S	0.11	0.09
PZ1M	0.13	0.19
PZ1D	0.12	0.16

Because of the low pumping rates, the drawdown data collected from this test were not used to determine the aquifer parameters.

6.2 Pumping Rate at 55 gpm With the Pump Intake Set at 24 ft btoc

6.2.1 Water Chemistry Results

The next test to be discussed was started at 12:30 on February 26, 2002, at a pumping rate of 55 gpm. A submersible pump was used for this test, with its intake set at a depth of 24 ft btoc. After 20 h the pump was shut off and a recovery test was completed. Figure 21 shows the location of the pump intake in relation to the lithology and the baseline sampling results.

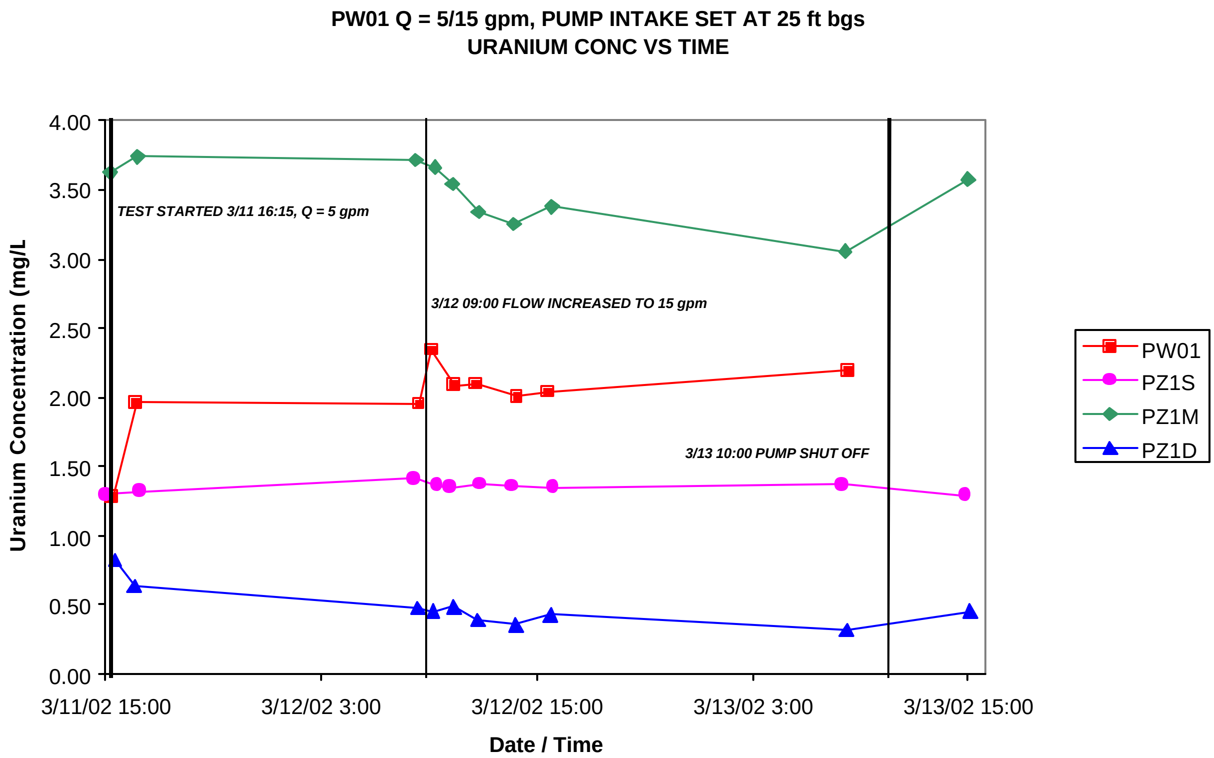


Figure 17. PW01: Q = 5/15 gpm—Test Uranium Concentration vs. Time

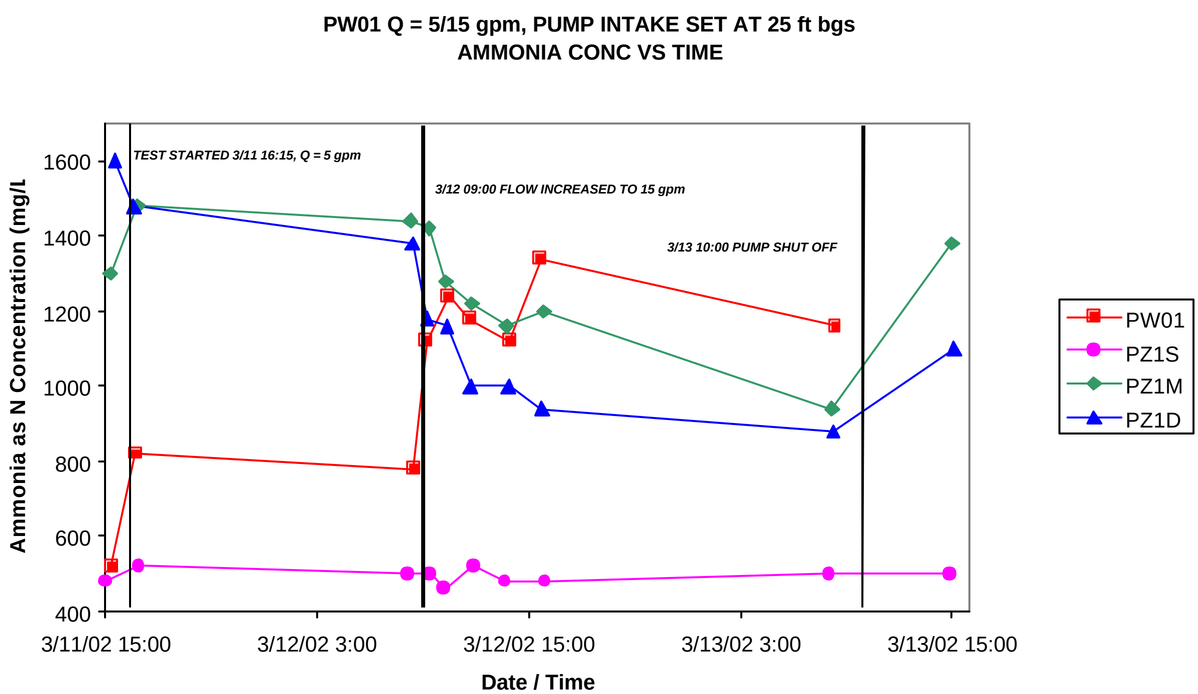


Figure 18. PW01: Q = 5/15 gpm—Test Ammonia Concentration vs. Time

A number of samples were collected at various times during this test. Sample times and results are included in Table 11. Appendix C contains a plot of the specific conductance data collected by the Troll 8000 probes. The specific conductance data obtained from the samples collected during the test (Table 11) provide more accurate values, and the data collected by the Troll 8000 probes provide the specific conductance trend during the test time period.

Table 11. Sample Results From 55 gpm Test, Pump Intake Set at 24 ft btoc

Well	Depth (ft btoc)	Date/Time	T (°C)	Cond (:S/cm)	SC (:S/cm)	Density (g/cm^3)	NH_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)	TDS (mg/L)
PW01	24	2/26/02 12:46	20.9	62,880	68,223	1.0294	1,420	15,237	11,807	2.258	38,667
PW01	24	2/26/02 15:38	20.6	59,480	64,937	1.028	1,420	15,106	11,436	2.255	38,567
PW01	24	2/27/02 8:20	21.2	55,400	59,736	1.0263	1,340	13,070	12,045	2.416	35,500
PZ1S	19	2/26/02 13:13	21.2	15,187	16,376	1.0076	540	1,443	7,322	1.215	12,171
PZ1S	19	2/26/02 15:32	21.7	15,240	16,265	1.008	540	1,435	7,311	1.211	12,143
PZ1S	19	2/27/02 8:17	21.6	15,180	16,234	1.0076	520	1,452	7,355	1.195	12,171
PZ1M	60	2/26/02 13:06	22.2	32,100	33,914	1.0157	1,080	3,338	13,398	2.816	21,829
PZ1M	60	2/26/02 15:26	22.2	27,650	29,212	1.0141	1,020	2,210	11,971	2.605	19,086
PZ1M	60	2/27/02 8:10	21.7	25,600	27,322	1.0136	860	1,886	11,992	2.529	17,957
PZ1D	75	2/26/02 12:46	21.4	129,400	138,955	1.0585	1,250	51,273	69,76	0.452	86,600
PZ1D	75	2/26/02 15:43	21.1	139,500	150,728	1.0584	850	51,773	67,11	0.366	87,700
PZ1D	75	2/27/02 8:04	21.9	165,200	175,597	1.0599	900	52,951	65,10	0.309	88,800

Cond = conductivity; SC = specific conductance
Notes: Depth measured as ft below top of casing (ft btoc)

Figure 22 is a plot of the specific conductance data during the test interval. Initial specific conductance conditions were not measured prior to this test because the well cluster was undisturbed for over 24 h. All initial concentrations were assumed equivalent to those measured during the baseline sampling event.

As expected (based on the test completed using a pumping rate of 5 and 15 gpm), there was a definite response to pumping measured in PW01. The specific conductance increased from approximately 17,300 :S/cm to over 68,000 :S/cm almost instantaneously after the pump was started. By the end of the pumping period, the specific conductance was greater than 59,700 :S/cm.

Well PZ1S again showed no response to pumping, even at this higher flow rate of 55 gpm. As in the previous test, a response to pumping was again measured in PZ1M. The specific conductance decreased to less than 34,000 :S/cm from an initial value of over 51,000 :S/cm. By the end of the pumping period, a specific conductance of approximately 27,300 :S/cm was measured. In Figure 22, observation well PZ1D potentially shows some response to pumping; specific conductance increased from approximately 139,000 to greater than 165,000 :S/cm.

Figure 23 was generated based on the sulfate/chloride ratio. As this figure shows, PW01 shows a response to pumping; the samples collected from PW01 initially have a high ratio that decreases sharply after the start of the test. The sample collected from PZ1M shows an inverse response to pumping, an initial low ratio followed by a sharp increase in response to the pumping. The sulfate/chloride ratio does not fluctuate in the samples collected from PZ1S and PZ1D.

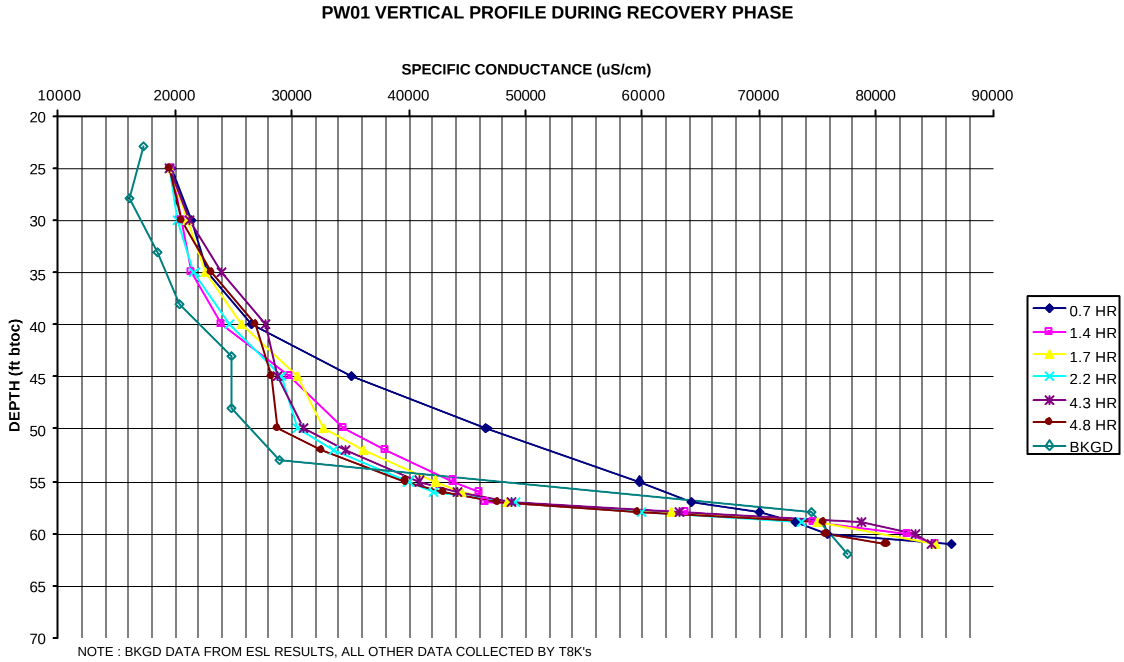


Figure 19. PW01: Q = 5/15 gpm—Test Vertical Profile Data Collected During the Recovery Phase

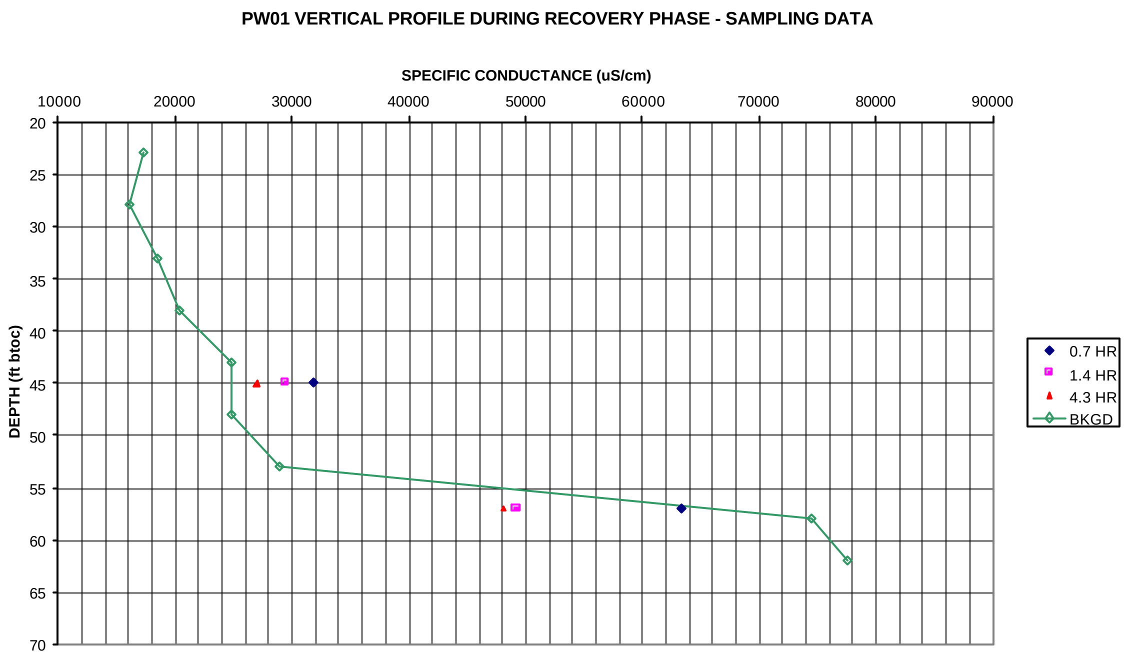
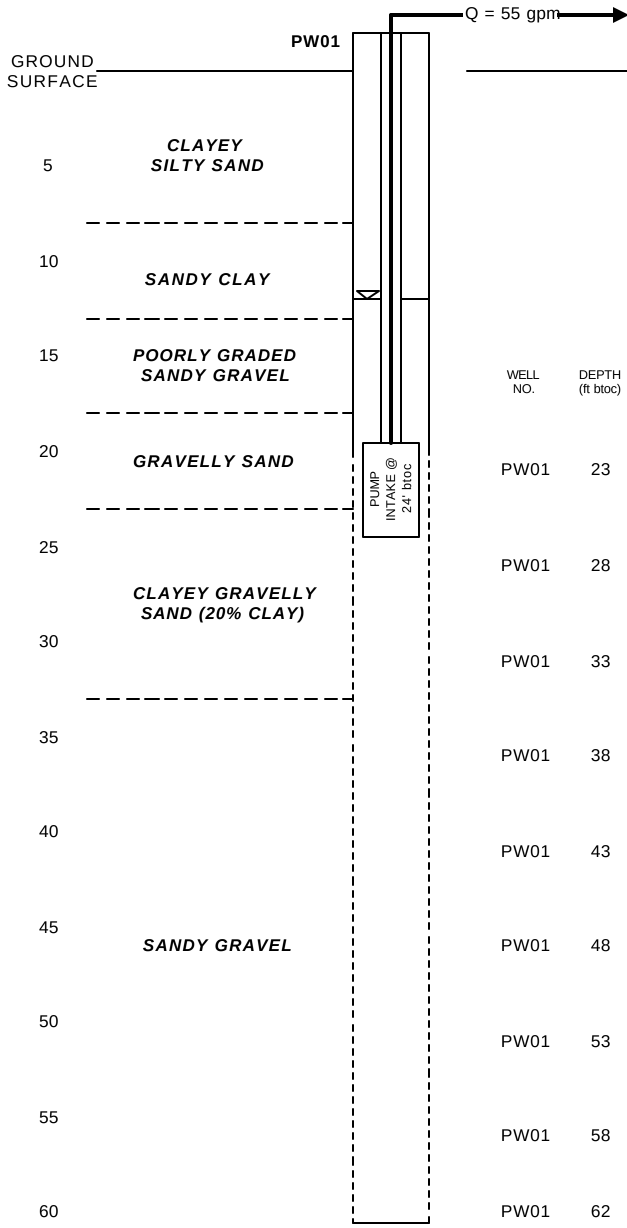


Figure 20. PW01: Q = 5/15—Test Vertical Profile Sampling Data Collected During the Recovery Phase

PW01
Q = 55 gpm
INTAKE SET 24 ft btoc



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^{-3})	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PW01	23	17358	1.0095	12400	500	1.224	1448	7325
PW01	28	16133	1.0094	12100	490	1.204	1425	7167
PW01	33	18522	1.0102	13525	770	1.762	1391	8775
PW01	38	20459	1.0106	15113	860	2.117	1447	10147
PW01	43	24789	1.0133	18120	860	2.512	1599	11905
PW01	48	24884	1.0134	18540	840	2.505	1615	11844
PW01	53	28997	1.0155	20580	980	2.867	2147	13348
PW01	58	74545	1.0333	46100	1620	3.064	16518	14569
PW01	62	77645	1.0336	46350	1560	2.974	16998	14510

Figure 21. PW01: Q = 55 gpm Test Scenario

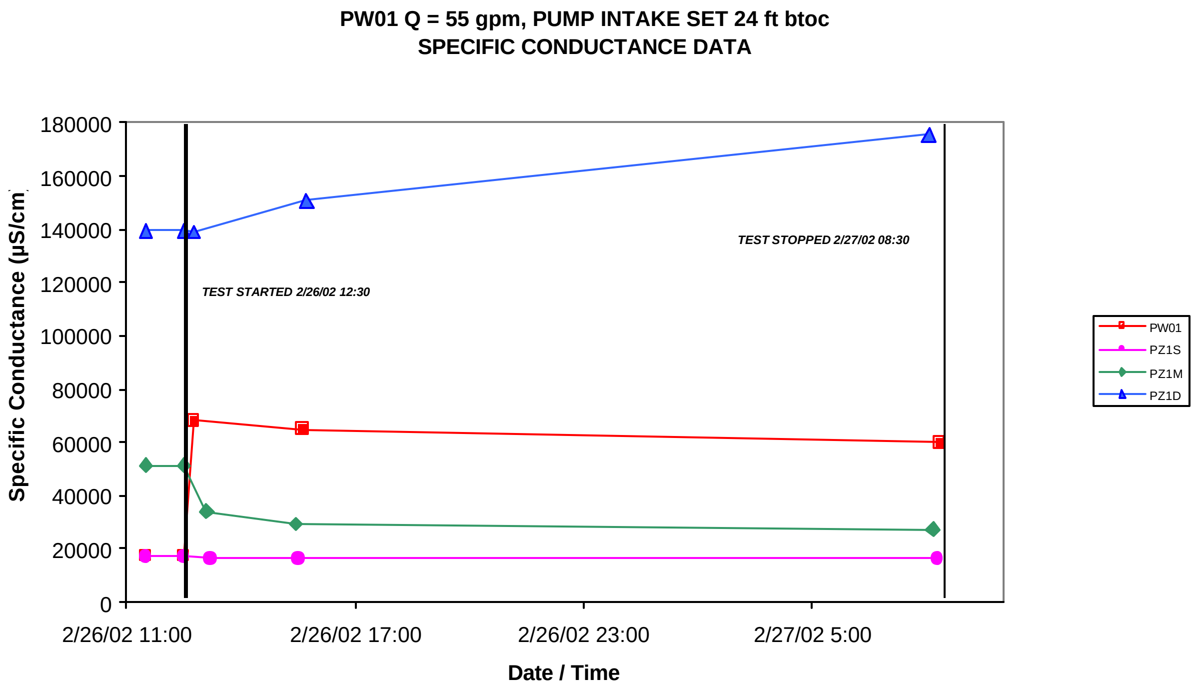


Figure 22. PW01: Q = 55 gpm—Test Specific Conductance vs. Time

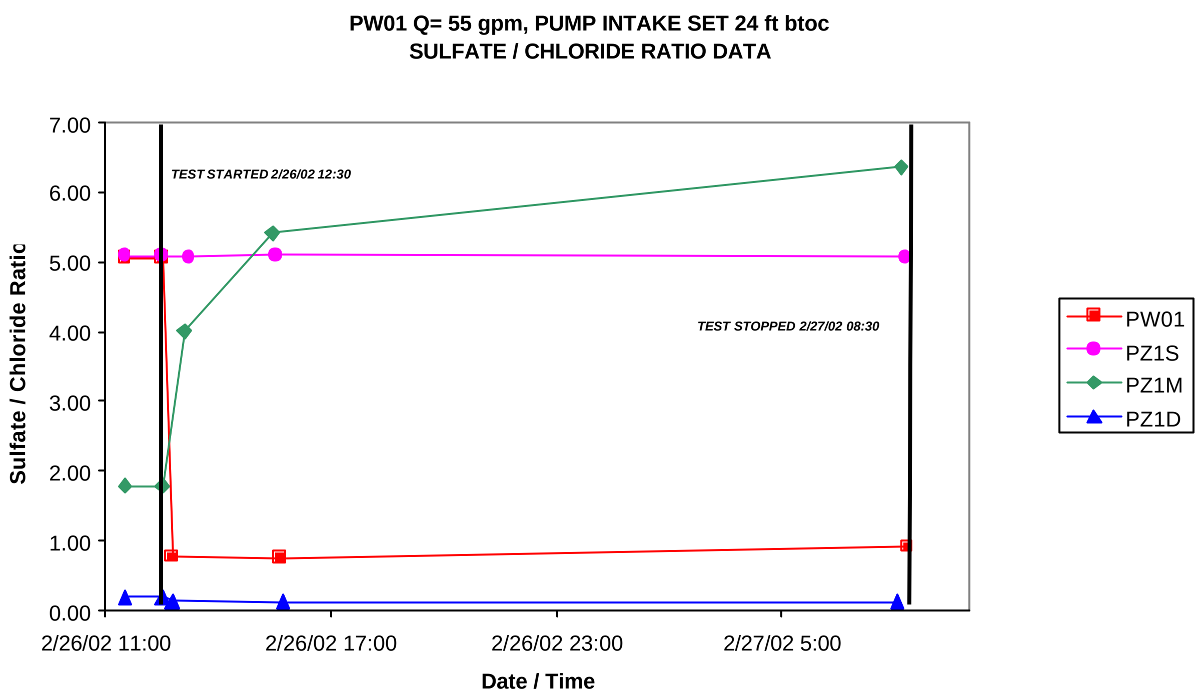


Figure 23. PW01: Q = 55 gpm—Test Sulfate/Chloride Ratio vs. Time

Figure 24 is a plot presenting the uranium concentrations measured during the test period. Analysis of samples collected from PW01 indicates that uranium increased from an assumed initial concentration of 1.224 to 2.258 mg/L after the pumping was started, and gradually increased to 2.416 mg/L by the end of the pumping period.

The samples collected from PZ1M and PZ1D exhibit an inverse trend in response to pumping. PZ1M samples decreased from an assumed initial concentration of 3.613 to 2.529 mg/L by the end of the pumping period, and uranium concentrations in PZ1D samples decreased from 1.053 to 0.309 mg/L during the same time period. Samples collected from PZ1S fluctuated between 1.195 and 1.345 mg/L during this test, suggesting that the pumping did not affect the shallow zone.

Measured ammonia concentrations are presented in Figure 25. Concentrations in samples collected from PW01 increased from 520 to 1340 mg/L in response to pumping. As with the trend in the uranium concentrations, the samples collected from PZ1M and PZ1D show a decrease in ammonia concentrations in response to pumping. PZ1M ammonia concentrations decreased from 1,500 to 860 mg/L at the end of the pumping period, and PZ1D concentrations decreased from 2,350 to 900 mg/L. There was no response detected in the samples collected from PZ1S, which had an ammonia concentration that fluctuated between 480 and 540 mg/L.

6.2.2 Water Elevation Results

A graph of the water level response to pumping during this test is presented in Appendix C. There was difficulty measuring water levels in the pumping well due to the size limitations created by using the 4-inch submersible pump inside the 4-inch well. In addition, the water level during the pumping phase dropped below the bottom of the transducer, providing unrepresentative data. Residual drawdown data associated with the recovery test PW01 were corrected and are considered representative. Table 12 presents the total drawdown data measured at the end of the pumping period.

Table 12. Total Drawdown Measured During the Q= 55 gpm Test

Well	Total Drawdown (ft)
PW01	3.5
PZ1S	0.41
PZ1M	0.92
PZ1D	0.87

Also included in Appendix C are the plots used to estimate the hydraulic parameters of the aquifer. Table 13 presents a summary of the results.

Table 13. Summary of Transmissivity and Hydraulic Conductivity Estimates From the Q = 55 gpm Test

Well	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Test Phase / Method
PZ1M	8,230	179	Pumping Phase / Hantush (1961)
PW01	3,226	70.1	Recovery Phase / Theis (1935)
PZ1M	8,917	193	Recovery Phase / Theis (1935)

Hydraulic conductivity estimates are based upon a freshwater saturated thickness of 46 ft. SMI used this same thickness to calculate the hydraulic conductivity (SMI 2001).

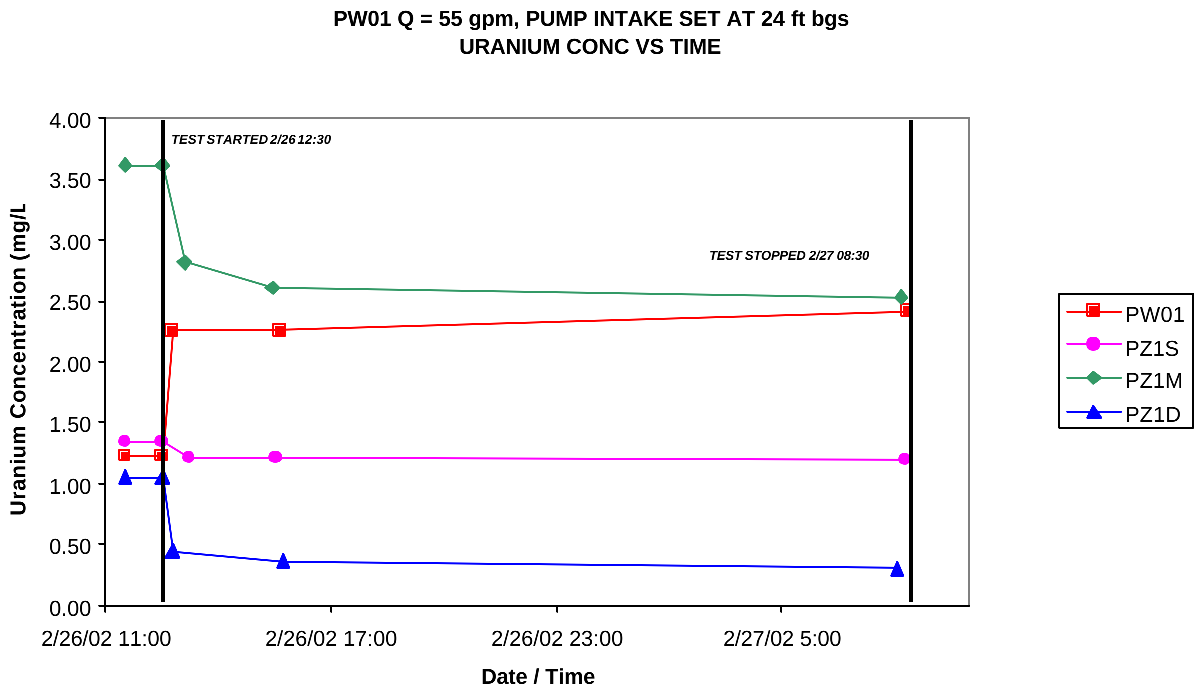


Figure 24. PW01: Q = 55 gpm—Test Uranium Concentration vs. Time

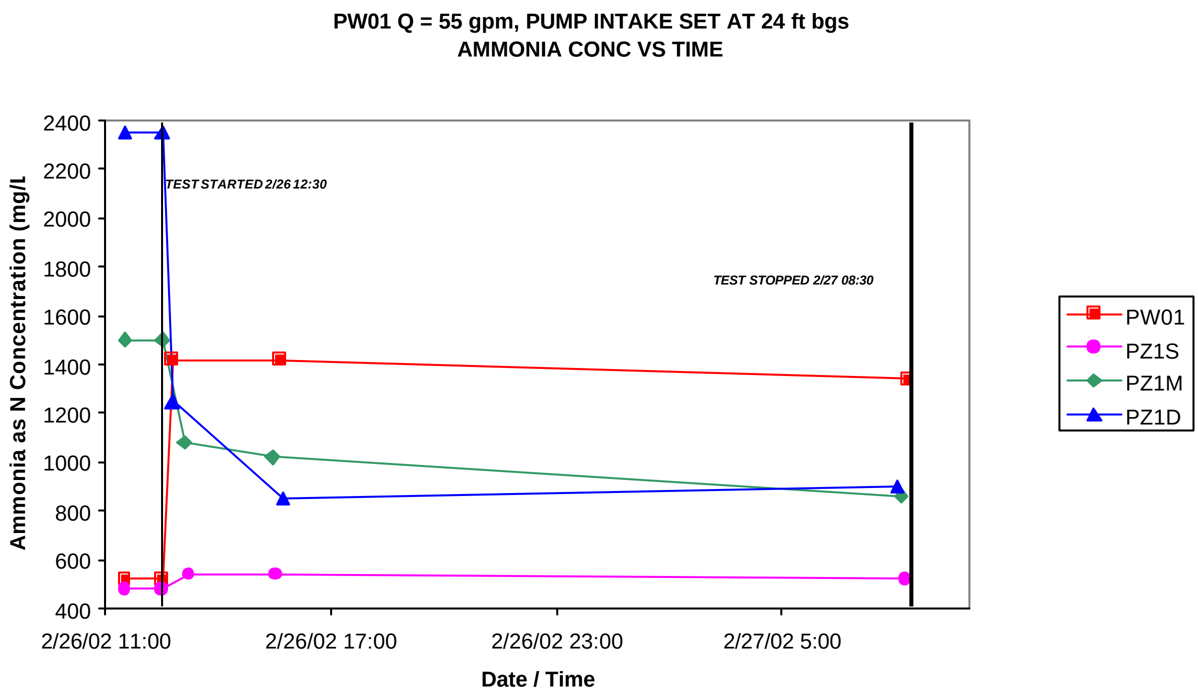


Figure 25. PW01: Q = 55 gpm—Test Ammonia Concentration vs. Time

6.3 Pumping Rate at 15 gpm, With the Pump Intake Set at 53 ft btoc

6.3.1 Water Chemistry Results

The next test was completed to determine the effect pump intake depth has on potential brine upconing. This test started at 09:00 on February 28, 2002, at a pumping rate of 15 gpm. A submersible pump was used for this test, with its intake set at a depth of 53 ft btoc. After 24 h the pump was shut off and a recovery test was completed. Figure 26 provides the location of the pump intake in relation to the lithology and the baseline sampling results.

A number of samples were collected at various times during this test. Sample times and results are included in Table 14. Appendix D contains a plot of the specific conductance data collected by the Troll 8000 probes. The specific conductance data obtained from the samples collected during the test (Table 14) provide more accurate values, and the data collected by the Troll 8000 units provide the specific conductance trend during the test time period.

Table 14. Sample Results From 15 gpm Test, Pump Intake Set at 53 ft btoc

Well	Depth (ft btoc)	Date/Time	T (°C)	Cond (:S/cm)	SC (:S/cm)	Density (g/cm^3)	NH_3 (mg/L)	Cl (mg/L)	SO_4 (mg/L)	U (mg/L)	TDS (mg/L)
PW01	24	2/28/02 9:22	21.2	53,520	57,708	1.0258	1,420	12,516	12,172	2.380	35,000
PW01	24	2/28/02 16:10	20.9	52,040	56,462	1.0264	1,400	12,514	11,930	2.376	34,367
PW01	24	3/1/02 8:10	21.3	49,560	53,329	1.0249	1,350	12,167	11,642	2.312	33,975
PZ1S	19	2/28/02 9:18	21.6	15,180	16,234	1.0071	540	1,436	7,315	1.220	12,014
PZ1S	19	2/28/02 16:15	21.6	15,200	16,256	1.0073	520	1,451	7,369	1.212	11,986
PZ1S	19	3/1/02 8:26	21.9	15,160	16,114	1.0068	500	1,454	7,300	1.185	12,070
PZ1M	60	2/28/02 9:11	21.9	30,400	32,313	1.0209	1,280	4,829	15,112	3.242	26,317
PZ1M	60	2/28/02 16:21	21.7	33,100	35,327	1.0182	1,100	3,759	14,251	2.991	23,700
PZ1M	60	3/1/02 8:19	22.3	33,750	35,585	1.0181	1,080	32,110	13,838	2.860	22,583
PZ1D	75	2/28/02 9:05	21.8	135,100	143,895	1.0577	1,400	50,185	7,166	0.523	83,800
PZ1D	75	2/28/02 16:27	22.3	129,200	136,225	1.0594	1,100	54,037	7,208	0.427	86,900
PZ1D	75	3/1/02 8:15	22.4	131,300	138,161	1.059	1,000	52,088	6,861	0.387	87,100

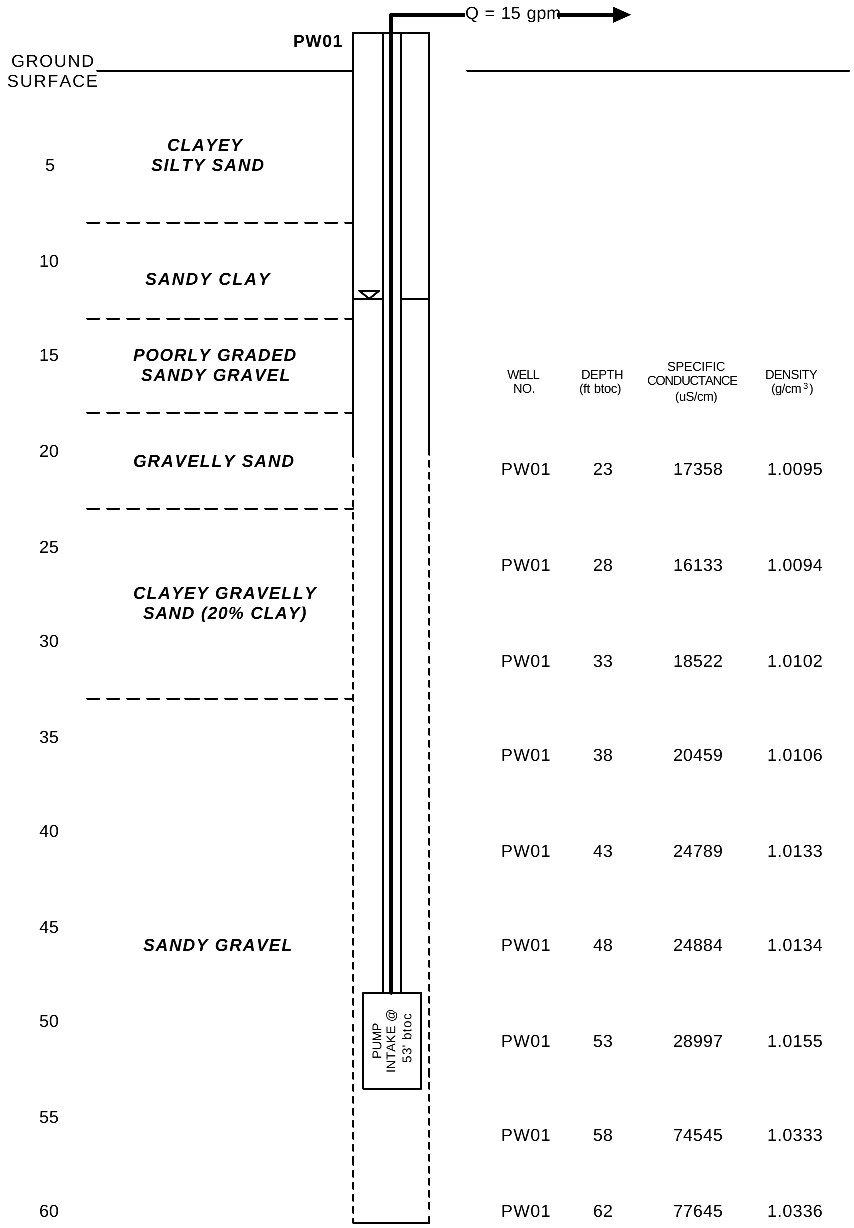
Notes: Depth measured as ft below top of casing (ft btoc); Cond = conductivity; SC = specific conductance

Figure 27 is a plot of the specific conductance data collected during the test interval. Initial specific conductance conditions were not measured prior to this test because the well cluster was undisturbed for over 24 h. As with the 55 gpm test, the initial concentrations were assumed to be equivalent to those measured during the baseline sampling.

The response in specific conductance values during this test was nearly identical to that observed during the 55 gpm test with the pump intake set 24 ft btoc. In PW01 the specific conductance increased from approximately 29,000 :S/cm to over 57,700 :S/cm almost instantaneously after the pump was started. By the end of the pumping period, the specific conductance was more than 53,000 :S/cm.

Well PZ1S again showed no response to pumping. As during the previous tests, a dilution response to pumping was measured in PZ1M. The specific conductance decreased to approximately 30,400 :S/cm from an initial value of over 51,000 :S/cm. By the end of the pumping period, specific conductance did rebound somewhat, eventually reaching over 35,500 :S/cm, but still below the starting level.

PW01
Q = 15 gpm
INTAKE SET 53 ft btoc



WELL NO.	DEPTH (ft btoc)	SPECIFIC CONDUCTANCE (uS/cm)	DENSITY (g/cm^3)	TDS (mg/L)	NH_3 as N (mg/L)	U (mg/L)	Cl (mg/L)	SO_4 (mg/L)
PW01	23	17358	1.0095	12400	500	1.224	1448	7325
PW01	28	16133	1.0094	12100	490	1.204	1425	7167
PW01	33	18522	1.0102	13525	770	1.762	1391	8775
PW01	38	20459	1.0106	15113	860	2.117	1447	10147
PW01	43	24789	1.0133	18120	860	2.512	1599	11905
PW01	48	24884	1.0134	18540	840	2.505	1615	11844
PW01	53	28997	1.0155	20580	980	2.867	2147	13348
PW01	58	74545	1.0333	46100	1620	3.064	16518	14569
PW01	62	77645	1.0336	46350	1560	2.974	16998	14510

Figure 26. PW01 Q = 15 gpm Test Scenario

Observation well PZ1D shows no significant response to pumping in Figure 27, and the values range from approximately 129,000 to just over 135,000 :S/cm.

Figure 28 was generated using sulfate/chloride ratio data. As this figure shows, PW01 shows the largest response to pumping from this deeper interval, with an initially high ratio value followed by a sharp decrease in response to pumping. This response is similar to that detected during the other tests.

Samples collected from PZ1M also show a different response, with the initial samples containing a low ratio followed by an increase once the test was started. However, the sample collected at the end of the test contained a sulfate/chloride ratio value below the initial value. PZ1S and PZ1D samples do not show a response to pumping based on the sulfate/chloride ratio data.

Figure 29 was generated from the results of uranium analysis of the samples collected during this test. Unlike in the previous tests, PW01 samples showed a decrease in the uranium concentration as the test progressed. The initial uranium concentration was 2.867 mg/L, and at the end of the pumping period the concentration decreased to 2.312 mg/L. Samples collected from PZ1M and PZ1D exhibited a similar response. PZ1M initial concentration was 3.613 mg/L, which decreased to 2.860 mg/L over the course of the test. The initial uranium concentration measured in the sample collected from PZ1D was 1.053 mg/L, and decreased to 0.387 mg/L during the pumping period. PZ1S concentrations showed no response to pumping, fluctuating between 1.345 and 1.185 mg/L.

Ammonia analysis results were used to generate Figure 30. Concentrations in samples collected from PW01 increased over the course of the test (from 980 to 1,350 mg/L), and concentrations in samples from PZ1M and PZ1D decreased during the same time period (from 1,500 to 1,080 mg/L and from 2,350 to 1,000 mg/L, respectively). As with the previous tests, samples from PZ1S showed no response; ammonia levels fluctuated between 480 and 540 mg/L.

6.3.2 Water Elevation Results

A graph of the water level response to pumping during this test is presented in Appendix D. Table 15 presents the total drawdown data measured at the end of the 24-h pumping period.

Table 15. Total Drawdown Measured During the Q= 15 gpm Test

Well	Total Drawdown (ft)
PW01	0.98
PZ1S	0.19
PZ1M	0.36
PZ1D	0.25

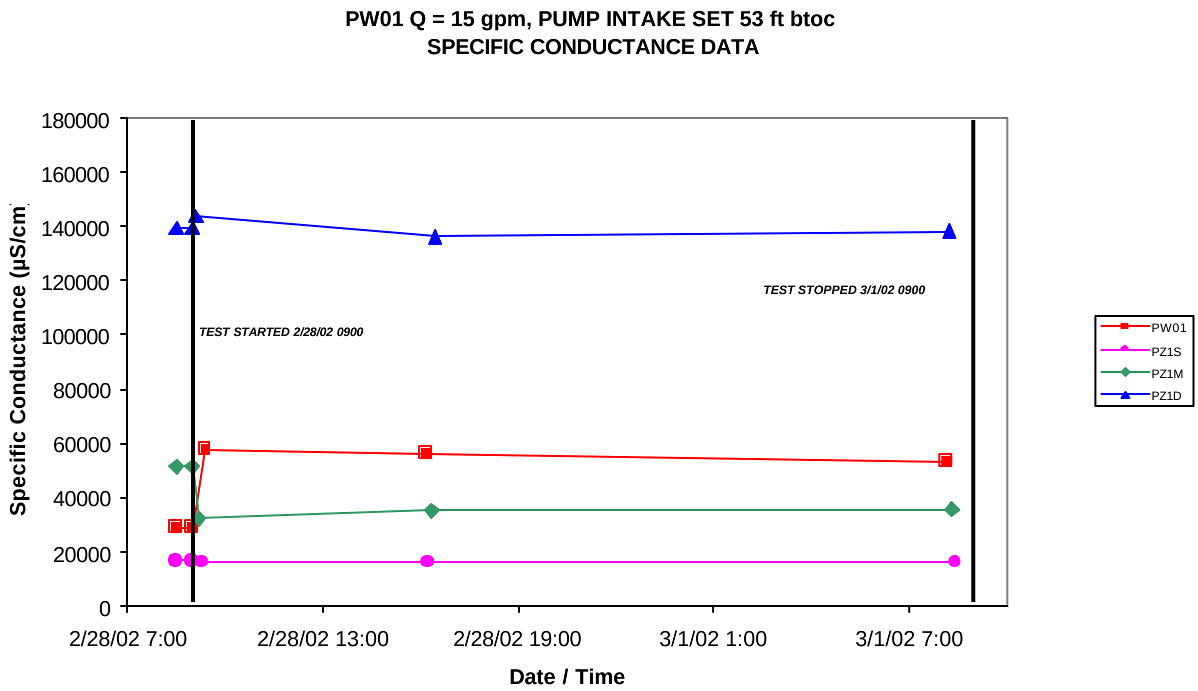


Figure 27. PW01: Q = 15 gpm—Test Specific Conductance vs. Time

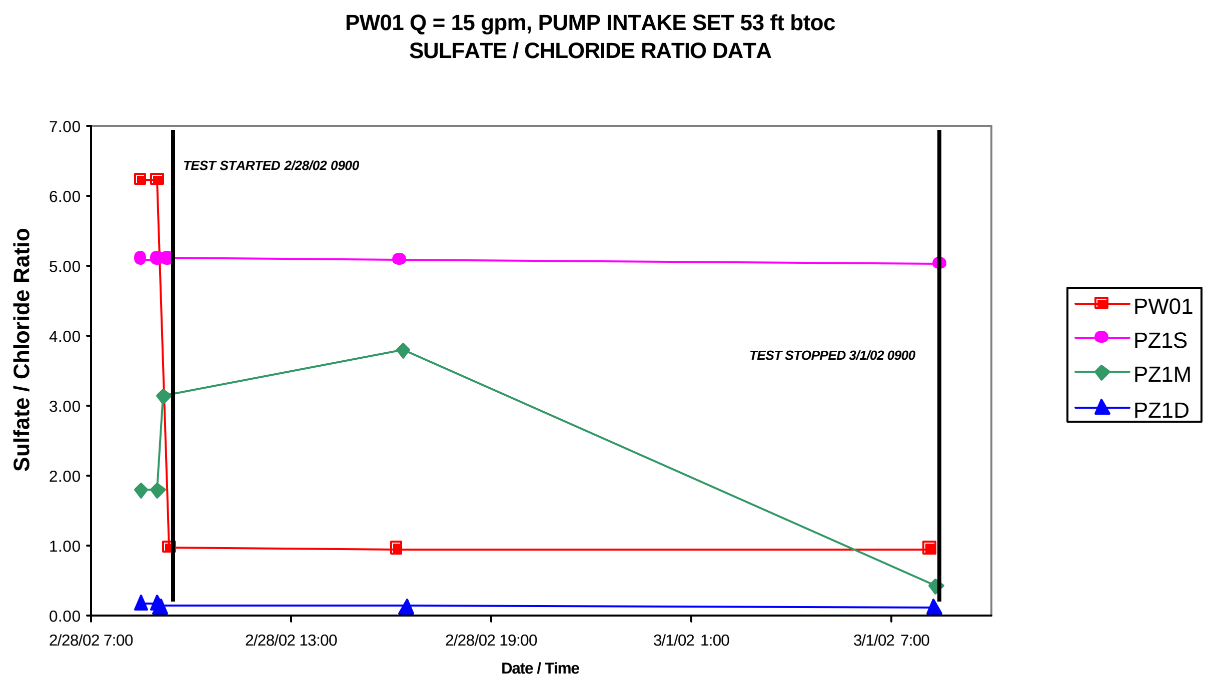


Figure 28. PW01: Q = 15 gpm—Test Sulfate/Chloride Ratio vs. Time

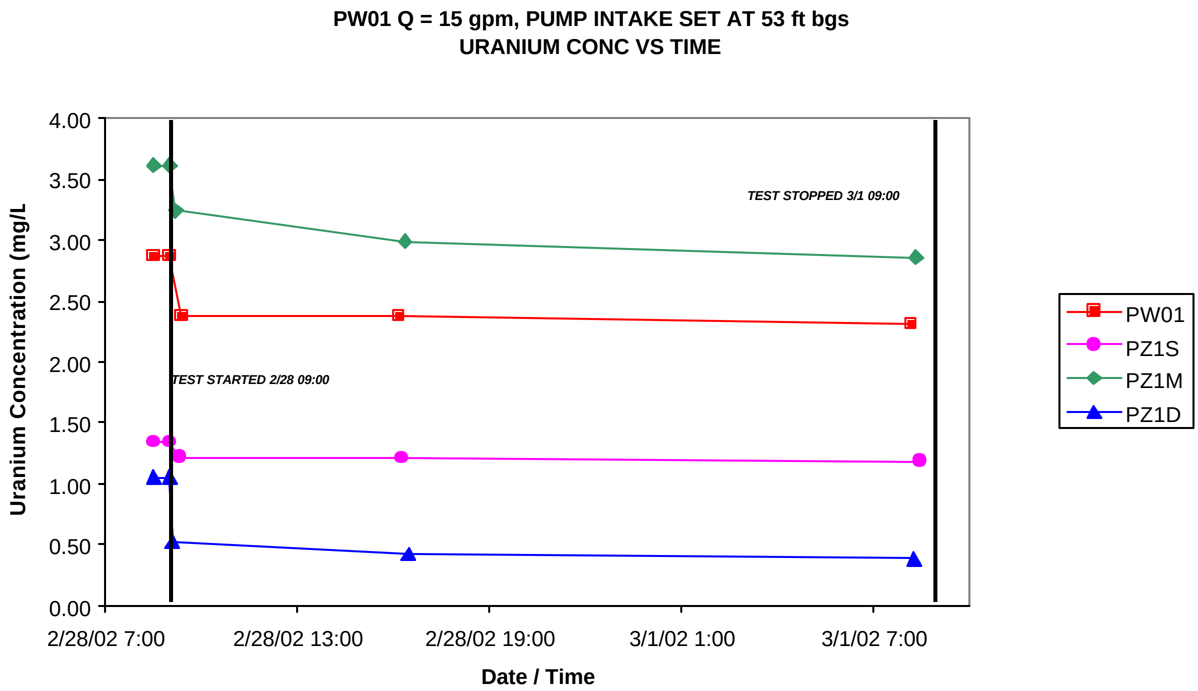


Figure 29. PW01: Q = 15 gpm—Test Uranium Concentration vs. Time

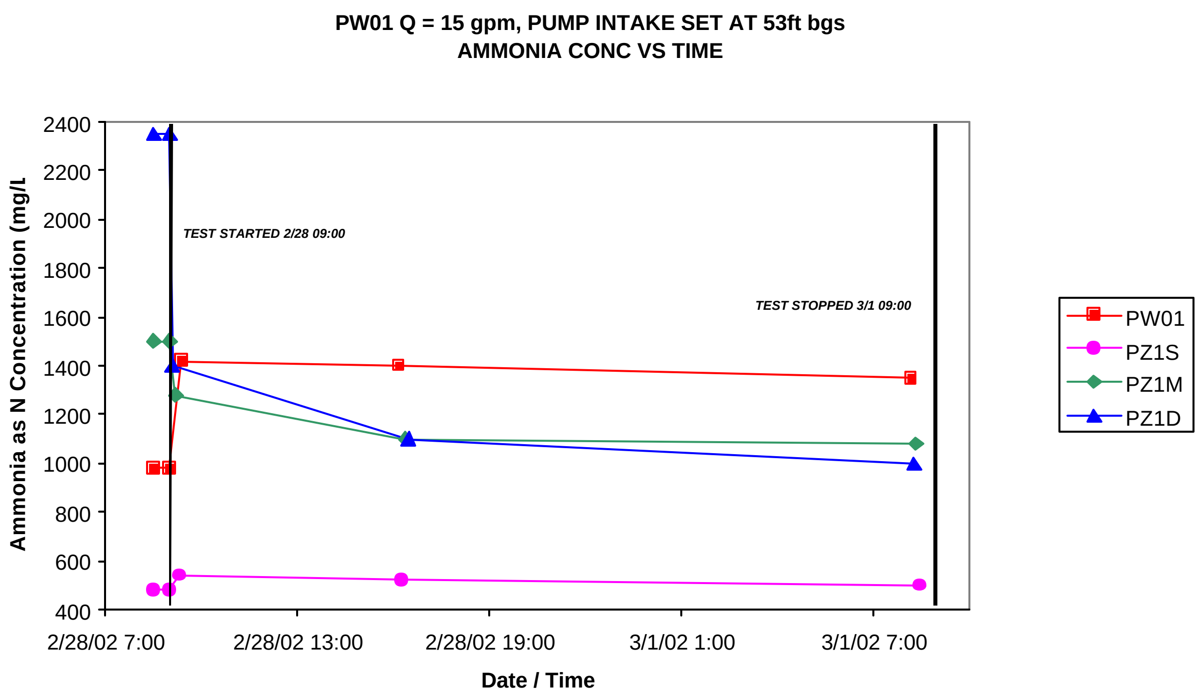


Figure 30. PW01: Q = 15 gpm—Test Ammonia Concentration vs. Time

Also included in Appendix D are the plots used to estimate the hydraulic parameters of the aquifer. Table 16 presents a summary of the results.

Table 16. Summary of Transmissivity and Hydraulic Conductivity Estimates From the Q = 15 gpm Test

Well	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)	Test Phase / Method
PW01	4,404	95.7	Recovery Phase / Theis (1935)
PZ1M	4,439	96.5	Recovery Phase / Theis (1935)

Hydraulic conductivity estimates are based on a freshwater saturated thickness of 46 ft. Because of the small amount of drawdown measured during this test, the resulting transmissivity and hydraulic conductivity estimates may not be representative.

End of current text

7.0 Summary and Conclusions

Based on the data collected during the baseline sampling, the following interpretations and conclusions can be made:

- A true brine unit has been defined as having a TDS concentration greater than 35,000 mg/L (Hanshaw and Hill 1969). Based on this definition, brine was encountered at the PW01 location between 53 and 58 ft btoc, and between 48 and 53 ft btoc at the PW02 location. The data suggest the brine zone surface lies below 78 ft btoc at the PW03 location.
- The depth to the brine zone increases to the north on site, as shown on Figure 31.
- There is a strong linear relationship between the specific conductance and the density, as well as the specific conductance and the TDS at PW01, PW02, and PW03 locations.
- The density of the underlying groundwater ranges from 1.0036 to 1.0618 g/cm^3.

Data collected from the PW01 well cluster indicate:

- Ammonia concentrations increase with increasing depth.
- Uranium concentrations showed the same trend with the exception of the sample collected from the deepest screened observation well.
- Based on the sulfate/chloride ratio data, two distinct water types are present: the water below 53 ft receives heavy influence from the underlying brine, and the shallower water is influenced by millsite activities.

Data collected from the PW02 well cluster indicate:

- Ammonia concentrations are constant from the water table to a depth of 48 ft btoc, at which point the concentration significantly increases to a depth of 60 ft btoc. The sample collected from the deepest observation well showed an ammonia concentration similar to those of the shallower samples.
- Uranium concentrations decrease with depth.
- Sulfate/chloride ratio data suggest two distinct water types are present at this location, and the significant difference is at a depth of approximately 35 ft btoc. This observation is consistent with the data collected during previous investigations.

Data collected from the PW03 well cluster indicate:

- Ammonia concentrations are consistently low from the water table to a depth of approximately 60 ft btoc, where the concentration increases significantly.
- Elevated uranium concentrations are at shallow depths and deepest depths; lower concentrations are between approximately 30 and 60 ft btoc.

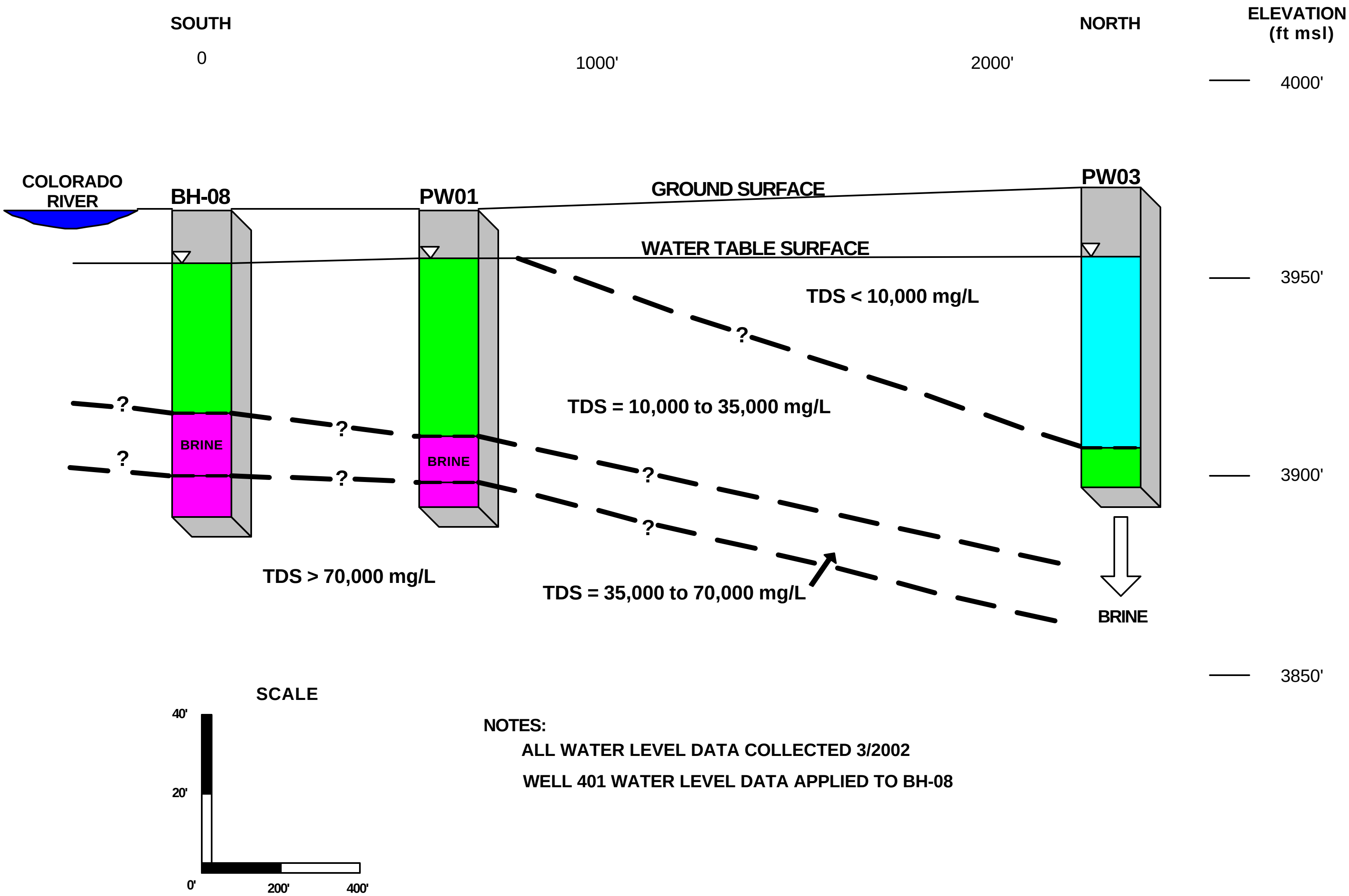


Figure 31. Depth to Brine Zone Across Site

- The data indicate the shallow water encountered at this location has a low (about 1.0) sulfate/chloride ratio, and the sample collected from the deepest screened observation well (78 ft btoc) had a ratio of 3.2. This trend is opposite of the trends at the other two locations, where samples collected from the shallow groundwater zones had the highest ratios, and the samples collected from the deepest zones had the lowest ratios.

The following is a summary of the data collected from the 5 and 15 gpm test with the pump intake set 25 ft btoc conducted at the PW01 cluster.

- Based on the specific conductance data, a pumping rate as low as 5 gpm with the PW01 pump intake near the top of the screen resulted in an increase of the discharge water specific conductance. Increasing the pump rate to 15 gpm further increased the specific conductance of the discharge water. Although there was no response detected in PZ1S, the specific conductance of PZ1M decreased during the 15 gpm pumping interval. Data collected from PZ1D were inconclusive.
- Sulfate/chloride ratio data suggest PW01 and the middle zone are affected by pumping. Water chemistry in the shallowest and deepest zones monitored by this test showed no response to pumping.
- Uranium concentrations of the discharge water increased during the pumping period, and the concentrations within the middle and deep zones decreased. After the pumping period ended, the uranium concentrations began to rebound. The shallowest zone was not affected by the pumping.
- Ammonia concentrations of the discharge water increased, and the middle and deep zone concentrations decreased during the pumping phase of the test. Both the middle and deep zone concentrations started to increase during the recovery phase. As with the uranium concentration data, the measured ammonia concentrations indicated there was no response to pumping in the shallowest zone.
- The pumping well returned to near static conditions after 1.5 h of recovery from this test.

These responses suggest:

- Despite the pump intake set in the shallow zone of the screen, the adjacent shallow zone of the aquifer did not recharge groundwater to the well, even with the low pumping rate of 5 gpm.
- The shallow, sandy portion of the aquifer is not as conductive as the deeper, underlying gravel unit. A preferential pathway is potentially located within the PW01 screen interval below 53 ft btoc.
- The groundwater zone screened by observation well PZ1M (57 to 62 ft btoc) recharges with groundwater having a lower specific conductance, possibly from a shallower zone.
- The profile data collected from PW01 during the recovery phase may indicate where more conductive zones are located within the screened interval of the well. The response measured at a depth of 45 ft btoc in which there was a constant change in the specific conductance over the measured time intervals suggests that a low conductivity zone may be adjacent to this depth, not allowing a quick rebound to the static conditions. The quick response (in which the largest change occurs just after the pumping is stopped) detected at 57 ft btoc suggests this depth may be influenced by a more conductive zone within the well.

The following is a summary of the data collected from the 55 gpm test with the pump intake set 24 ft btoc conducted at the PW01 cluster.

- At this increased pumping rate the discharge water specific conductance increased to higher measured values compared to the 5/15 gpm test. Again, no response was detected in PZ1S, and the specific conductance decreased in PZ1M and increased in PZ1D during the pumping phase.
- Sulfate/chloride ratio data suggest again that PW01 and the middle zone respond to pumping, and the shallowest and deepest zones monitored during this test do not.
- Uranium concentrations of the discharge water increased during the pumping period, and the concentrations within the middle and deep zones decreased. Uranium concentration data also suggest the shallowest zone was not affected by the pumping.
- Ammonia concentrations of the discharge water increased, and the middle and deep zone concentrations decreased during the pumping phase of the test. As with the uranium concentration data, the ammonia concentration data indicate there was no significant response to pumping in the shallowest zone.
- Analysis of drawdown data collected from observation well PZ1M indicates the transmissivity of the gravel unit within the aquifer ranges from 3,225 to 8,917 ft^2/day. This range is comparable to the results of previous tests conducted at the Moab Project Site (4,280 to 9,989 ft^2/day).

These responses suggest:

- As in the 5/15 gpm test, the zone adjacent to the pump intake within the shallow zone of the aquifer did not recharge groundwater to the well. The discharge water source appears to originate from the deepest zones of the screened interval.
- The middle zone appears to be affected by groundwater originating from shallower zones during pumping.
- Despite an increased pumping rate (over 300 percent higher than that of the 15 gpm test), the specific conductance of the discharge water during the 55 gpm test was only 10 percent higher than the specific conductance measured during the 15 gpm pumping rate test. A higher pumping rate apparently does not necessarily result in a significant increase in the specific conductance of the discharge water.

The following is a summary of the data collected from the 15 gpm test with the pump intake set 53 ft btoc conducted at the PW01 cluster.

- The specific conductance of the discharge water increased during this test, and values were similar to those measured during the 55 gpm test. There was no significant response in water chemistry to pumping detected in wells PZ1S and PZ1D; however, in PZ1M a dilution effect was observed.
- Sulfate/chloride ratio data suggest again that PW01 and the middle zone respond to pumping, and the shallowest and deepest zones monitored during this test do not.
- In contrast to results of the previous tests, uranium concentrations of the discharge water decreased during the pumping period, as did the uranium concentrations within the middle

and deep zones. Uranium concentration data also suggest the shallowest zone was not affected by the pumping.

- Ammonia concentrations of the discharge water increased, and the middle and deep zone concentrations decreased during the pumping phase of the test. As with the uranium concentration data, the ammonia concentration data indicate there was no significant change in water chemistry when pumping in the shallowest zone.
- Analysis of drawdown data collected during this test indicates the transmissivity of the gravel unit within the aquifer ranges from 4,404 to 4,439 ft^2/day. This range is also within the range of values measured during previous tests conducted on site.

These responses suggest:

- The depth of the pump intake influences the specific conductance of the discharge water.
- The middle zone was initially diluted by shallow groundwater during the first portion of the pumping phase, then was affected by groundwater from a deeper zone during the later stages of the pumping phase.

End of current text

8.0 Recommendations

Despite providing useful, representative data, these tests had limitations that must be kept in mind while interpreting these data. Most importantly, the limitation of the pumping interval of only 24 hours suggests a starting point for further testing, as opposed to providing definitive results. The completion of a long-term aquifer test using a pumping well screened over the shallow, sandy portion of the aquifer is recommended.

The data suggests that in order to avoid increased specific conductance of the discharge water within a pumping well located in an area adjacent to a shallow brine zone, the completion depth of the pumping well should be drilled such that the screen does not penetrate the gravelly sand unit of the alluvial aquifer.

The lower gravelly sand portion of the aquifer is much more conductive than the shallower, sandy unit, and is apparently responsible for the most of the recharge into pumping well PW01. To avoid increased specific conductance within the discharge water near PW01, a pumping well should be drilled to a depth of approximately 25 ft bgs. At this depth, the well should be screened only in the shallow sandy unit, with the bottom of the screen set in what has been described as a clayey gravelly sand unit with up to 20 percent clay. This finer-grained unit overlying the top of the more conductive sandy gravel unit may provide some protection against upward flow from the underlying unit.

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9.0 References

Environmental Simulations, Inc., 1999. *Guide to Using Aquifer Win32*, Version 1.30

Hanshaw, B.B., and Hill, G.A., 1969. "Geochemistry and Hydrodyanmics of the Paradox Basin Region, Utah, Colorado, and New Mexico," *Chem. Geol*., (4) 263–294.

Kruseman, G.P., and DeRidder, N.A., 1991. *Analysis and Evaluation of Pumping Test Data,* International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

Oak Ridge National Laboratory (ORNL), 1998. *Limited Ground Water Investigation of the Atlas Corporation, Moab Mill, Moab Utah*, prepared for the U.S. Fish and Wildlife Service, Salt Lake City, Utah.

Shepard Miller, Inc. (SMI), 2001. *Site Hydrogeologic and Geochemical Characterization and Alternatives Assessment for the Moab Mill Tailings Site, Moab, Utah*, April.

Theis, C.V., 1935. "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage," *Am. Geophys. Union Trans.*, (16), 519–524.

U.S. Department of Energy (DOE), 2001. *Moab Health and Safety Plan,* GJO–MOA1.3, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

———, 2002a. *Work Plan for Characterization of Groundwater Brine Zones for Interim Remediation Activities at the Moab, Utah, UMTRA Project Site*, GJO–MOA1.9-2, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado, February.

———, 2002b. *Chemistry of Ground Water in the Colorado River Sandbar Area - Moab, Utah, UMTRA Project Site*, ESL–RPT-2002-03, prepared for the U.S. Department of Energy Grand Junction Office, Grand Junction, Colorado.

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Appendix A

ESL Data Package—Pump Test Groundwater Samples

Appendix B

PW01 Q = 5/15 gpm Test Data

Appendix C

PW01 Q = 55 gpm Test Data

Appendix D

PW01 Q = 15 gpm Test Data